METAL
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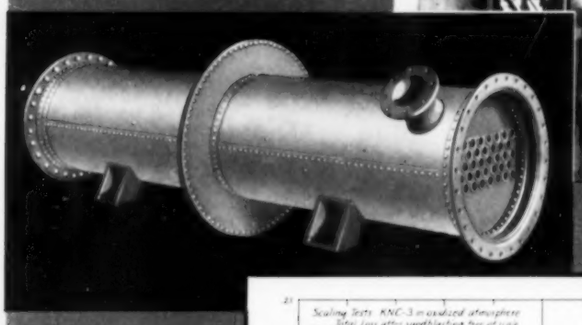
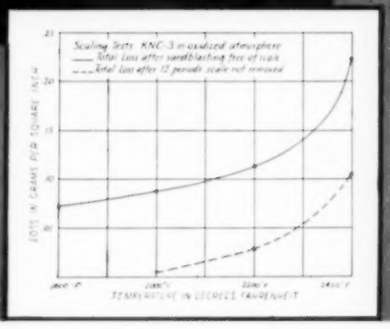
KEEPING A STEP AHEAD WITH ENDURO

Enduro ideal for refinery equipment.



Heat Exchanger of Enduro—for longer life.


Scaling Tests KNC-3 in oxidized atmosphere
Total Loss after sandblasting free of scale
Total Loss after 12 periods scale not removed
LOSS IN GRAMS PER SQUARE INCH
TEMPERATURE IN DEGREES FAHRENHEIT

ENDURO FOR HIGH TEMPERATURE APPLICATIONS

Enduro, Republic's Perfected Stainless Steel, brings to designers of equipment subjected during operation to high temperatures, high stresses and corrosion a medium well suited to the solution of vexing problems.

Several grades of Enduro are available, each possessing characteristics of strength, toughness, oxidation resistance and workability that makes it suitable for a particular class of service, such as refinery equipment, chemical equipment, furnace parts, oil burner parts, retorts, oven linings, heat exchangers and a host of other industrial applications.

Enduro Nirosta can be supplied in billets, rough turned tube rounds, bars, sheets, plate and hot rolled strip. Let our metallurgists tell you how this enduring metal will meet your most exacting requirements, and recommend the most suitable analysis.

CENTRAL ALLOY DIVISION
REPUBLIC STEEL CORPORATION
MASSILLON, OHIO

ENDURO
REPUBLIC'S PERFECTED STAINLESS STEEL

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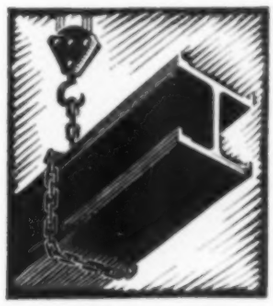

Metal Progress

Published and Copyrighted 1931, by the **American Society for Steel Treating,** *7016 Euclid Avenue, Cleveland, Ohio. Issued monthly, $5 a year, $1 a copy. Entered as second-class matter, Feb. 7, 1921, at the post-office at Cleveland, O., under the Act of March 3, 1870.*

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Ernest E. Thum, Editor.

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GOOD WILL BASED ON GOOD STEEL

The ETCH TEST

An important phase *of* Timken quality control

Uniformity of physical structure is one of the most important necessities in alloy steel, for upon it depends, to a very great extent, the reliability of the steel in service.

Timken quality control leaves nothing to chance in connection with this vital factor.

So careful and thorough is Timken manufacturing practice, and so complete and rigid Timken testing routine, that there is hardly a possibility for physically defective steel to be produced or passed.

As an additional precaution, however, the etch test is used in the nature of a surprise check.

This test is not applied to every heat, but may be called for at any time by the chief metallurgist unknown to the furnace men, rollers and other operators.

While expensive to make, the etch test is infallible in results.

It may be made while the steel is in the form of blooms, billets or bars, and the method, as practiced by Timken, is as follows:

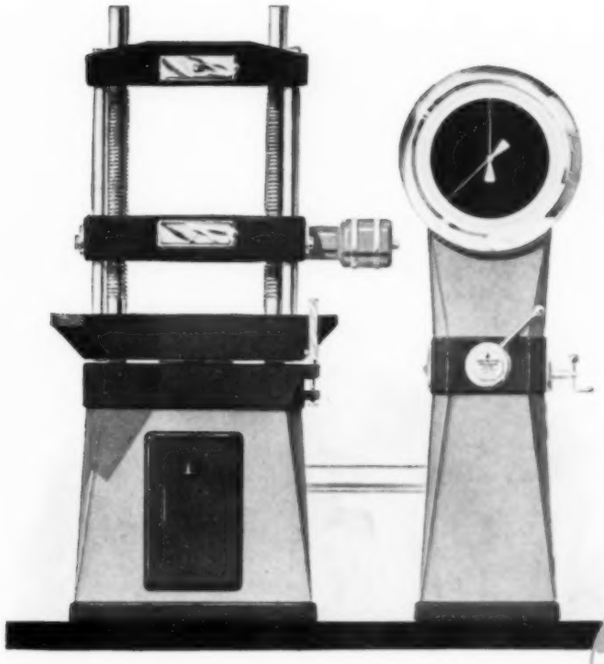
Full sections of steel are sawed off the blooms, billets or bars as the case may be. These pieces of steel are then etched in an acid solution, which clears the surface of the steel of saw marks and other superficial irregularities and reveals the true structure of the metal.

The etched sections are then critically examined by the metallurgists for alloy segregations, slag inclusions, pipes, seams or other structural imperfections detrimental to physical quality. The Timken Steel and Tube Company, Canton, Ohio. Detroit, Chicago, New York, Los Angeles, Boston.

TIMKEN

Electric Furnace and Open Hearth

ALLOY STEELS



JUDGE FOR YOURSELF!

IF beauty in machine design means anything to you who work with machines, then the above artist's sketch of Riehle's new precision Hydraulic Universal Testing Machine with the new Mercury Float Recording Unit will tell you volumes. • Beauty in design, however, is but an incident in the conception of this machine. Far more important than its general appearance is the creative engineering that gives to you a machine so far in advance of present-day machines that it is truly tomorrow's machine. • See this machine at the A. S. T. M. Convention in Chicago—June 22nd to 26th—where it will make its first public appearance. • Visit booths Nos. 19 and 21—see this machine in operation—and judge for yourself.

The new Riehle catalog is ready for distribution. *Send for your copy.*

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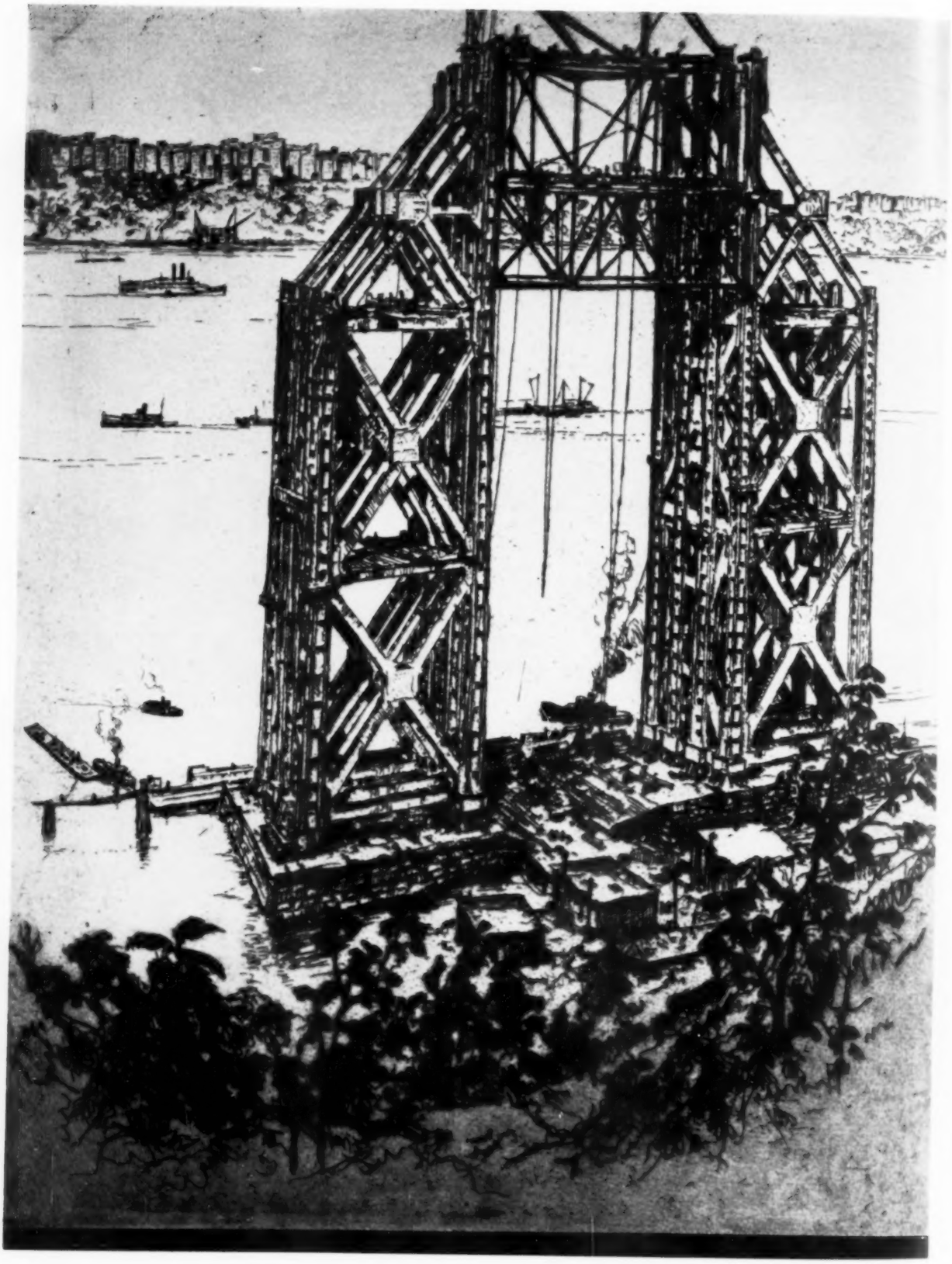
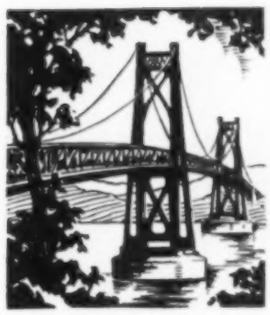


Hudson River Bridge Under Construction

Etching by O. Kuhler

Strong Steels for Bridges

By D. B. Steinman
Consulting Engineer, New York



DEVELOPMENT of longer span bridges has created an impelling need for high strength steels. That the economy of utilizing stronger steels increases with the span-length, is axiomatic. In certain cases, as in the stiffening trusses of long suspension spans, economic desirability yields to compelling necessity as the governing consideration; the material must be suited to the high unit stresses determined by other controlling features of the design. Other reasons, besides dead load reduction, for adopting high strength steels are to keep large sections and thicknesses in shapes and plates down to workable limits.

Accordingly, the bridge engineer looks to the metallurgist to furnish high strength steels that shall be suitable, safe, dependable, and economical. (1) Economy requires that the material shall not only be comparatively low in first cost, but that it shall also be free from expensive requirements in fabrication and erection. (2) Dependability requires that the material shall be subjected to exhaustive testing, study and experimental research before it is offered for utilization. (3) Safety requires that the material shall not have or develop any unknown or unsatisfactory service characteristics, such as time effects, internal stresses, brittleness, or non-uniformity. (4) Suitability requires that the metallurgists and the producers study the conditions under which the material is to be used, including the form of the members and the connections, to make certain that no unknown or unconsidered property of the material will adversely affect its safe and economical serviceability.

The objective in developing high strength steels should be to obtain high elastic limit with unimpaired ductility. The elastic limit (or yield point) determines the ultimate strength for columns, and is also the basis for fixing working unit stresses for other members.

Except where economy or other desiderata dictate the adoption of high-strength steels, the bridge designer prefers low strength material in order to retain maximum stiffness in the structure. Higher unit stresses mean greater deflections under load. Of two designs of equal

Metropolis Bridge, Over the Ohio, Has the World's Longest Simple Truss Span—720 Ft. Eyebars and pins are of nickel steel, balance of structural grade. Completed 1916

cost and safety, the heavier design is to be preferred, for its rigidity and for longevity (either for corrosion resistance or for future increase in live loadings.)

Nickel Steel In the Older Bridges

The high strength steels that have thus far been successfully used in bridge construction have been of three classifications: alloy steel, heat treated carbon steel and cold drawn high carbon steel. The latter classification (bridge wire) will not be discussed in this article. In the alloy steels we have used extensively nickel steel, silicon steel, and medium manganese steel. In the heat treated steels we have eyebars in both mild grade and high tension grade.

The Eads Bridge spanning the Mississippi River at St. Louis, completed in 1874, was the first important American bridge to use steel. It was also the first bridge in the world to employ alloy steel. The tubular chord members of the hingeless arch ribs were made of a low chromium steel of 100,000 ultimate and 40,000 lb. per sq. in. elastic limit. In the undeveloped state of the art, this material was not uniform and gave much trouble in fabrication.

Alloy steel for bridges returned into favorable consideration with the advocacy by Gustav Lindenthal, about 1900, of nickel steel for use in the Manhattan, the Queensboro, and the record-breaking Quebec Bridge.

Although Lindenthal's design for the Manhattan Bridge with cables of nickel steel eyebars was turned down by the political authorities, the adopted design with parallel wire cables

retained nickel steel for the stiffening trusses (top and bottom chords and diagonals). Over 8,000 tons of nickel steel were used for these members in the main and side spans, out of a total of over 44,000 tons of steel in the entire bridge. Ordinary steel was used for the vertical hangers in the stiffening trusses, since neither economy nor stress conditions called for stronger steel here. The nickel steel chords and diagonals are riveted, built-up members, and are generally required to take reversals of stress. The bridge was completed in 1909. Nickel steel eyebar chains, as suggested in the original Manhattan Bridge design, were used for the Cologne suspension bridge over the Rhine, completed in 1915, with a main span of 605 ft.

Nickel steel eyebars, as proposed by Lindenthal, were adopted in 1902 for the tension members (top chords and diagonals) of the Queensboro Bridge (a cantilever design completed in 1908). The eyebars were up to 16x2 in. cross section, the largest made up to that time. Pins were also of nickel steel. About 6,000 tons of nickel steel was used in the structure, out of a total of 53,000.

The second Quebec Bridge (also a cantilever, completed in 1918) utilized nickel steel as the principal material both for tension members of eyebars and for built-up members to take compression or reversal of stress. Nickel steel rivets were not adopted, due to insufficiency of tests and a time delay.

In the Municipal Bridge at St. Louis, nickel steel was used throughout for both eyebars and compression members.

Nickel steel was also used for the eyebars and pins of the Metropolis Bridge over the Ohio River, completed in 1916; its simple truss span of 720 ft. holds the record.

Among the recently completed suspension bridges is the Philadelphia-Camden Bridge (completed in 1926), wherein nickel steel was used for the top and bottom chords of the stiffening trusses, to meet the unit stress requirements imposed by the conditions of elastic deflection of the spans. The amount of nickel steel so used was over 5,000 tons, out of a total of over 18,000 tons of various kinds of steel used in the bridge.

Long Bridges Demand Best Steel

The Hudson River Bridge at Fort Lee is now being built as a single-deck structure, without any stiffening truss.

The top chord of the future stiffening truss is being built into the present structure at roadway level and serves as a chord for a wind truss. It is made of nickel steel. The specifications called for silicon steel chords for the alternative design with eyebar cables, and for nickel steel chords in the adopted design with wire cables, since the greater elastic deflection of the higher-stressed wire cables produced stresses in the stiffening truss too high for silicon steel to

Carquinez Cantilever Bridge, Completed 1927, Vies With the Longest Cantilever Spans in the United States. Eyebars are of mild grade of heat treated steel, and compression members are of structural silicon steel. The author was designing engineer

World's Longest Arch, 1652 Ft., Nearing Completion. Kill Van Kull Bridge uses over 5,000 tons of medium manganese steel in main compression members

carry. The future bottom chords will also be of nickel steel, but diagonals and the bottom chords will not be added to the structure until the volume of traffic makes it necessary to add the lower deck.

Nickel steel, although showing high physical properties in the standard test specimens, is subject to certain limitations as, for instance, with respect to punching or drifting of rivet holes. Nickel steel is also difficult to roll without surface defects.

This steel's principal disadvantage, however, is the cost of the material. A differential of 2½¢ per lb., or more, for the standard 3½% nickel steel over ordinary carbon steel, and an increase of about 10% in shop costs, now limit the economic applications of nickel steel to exceptional cases where less costly alloys will not have the requisite strength.

For general purposes as an economical high strength structural alloy, nickel steel has been superseded by silicon steel. Where economy alone is the governing consideration, nickel steel cannot compete with silicon steel. Silicon steel is the least expensive of the high strength structural steels. In fact it is the least costly of all bridge steels per unit of strength. Silicon steel is obtainable at a price differential of 1¢ or less over ordinary carbon steel, and it would require a very long span indeed to make a favorable economic showing for nickel steel against this less expensive alloy.

Silicon steel has been used successfully in a large number of modern bridges. It was used for all the main members (except eyebars) of the Metropolis Bridge in 1916. It was adopted for the towers and compression members of the Carquinez cantilever bridge, for the towers of the Philadelphia-Camden suspension bridge, for the stiffening trusses of the Mount Hope, Detroit, and St. Johns suspension bridges, for most of the truss members of the Montreal Harbor bridge, and for the towers, floor, and anchor girders of the Hudson River suspension bridge. The last-named structure uses 33,000 tons of it.

Silicon steel is subject to certain limitations in respect to specifications, design, and inspection, which should be kept before the bridge engineer. In the first place, not all sizes and shapes have been available in silicon steel. Furthermore, sheared edges require to be planed and carefully inspected to reveal seams or laminations.

Silicon steel is properly used for built-up compression members, but should not be used for tension members except with extreme caution. If used for tension members, sections and details should be generously proportioned, with excess material at connections for safe distribution of stress. Designs for tension members of silicon steel, including connections, should be checked by full-size tests to destruction.

Manganese Steel Used In Long Arch

Medium manganese steel (1.5% Mn) was developed as a structural alloy steel in time to be adopted for the Kill Van Kull arch bridge now approaching completion for the Port of New York Authority. With its span of 1,652 ft., this will be the longest span arch in the world. Over 5,000 tons of manganese steel went into this structure.

Tests on half-size columns for this bridge showed a 50% increase in strength over ordinary structural steel; but tension tests of members made of this material with riveted connections yielded disquieting results, and modifications of design were necessitated to assure the necessary safety.

Apparently, all is not known that should be known regarding the behavior of alloy steels when used for riveted tension members, and such use should be avoided until more complete and reassuring information can be furnished by the metallurgists and the producers.

Heat treated steel eyebars, mild grade, with a guaranteed minimum ultimate strength of 80,000 and a guaranteed minimum yield point of 50,000 lb. per sq. in., have been available to bridge engineers since 1915.

Following their successful application in six smaller bridges, they were adopted for the principal tension members of the Carquinez Strait Bridge in California. This cantilever structure, with two main spans of 1,100 ft. each, was completed in 1927. For the mild grade heat treated eyebars, the adopted unit stress was 50% higher than that specified for ordinary structural steel. Brinell tests were adopted to test the uniformity of the eyebars throughout their length and with one another.

The heat treated eyebars, mild grade, appear to be a fully safe and satisfactory material for use for bridge members in tension. Their cost is only 1¢ above the cost of ordinary structural steel eyebars.

After several years of experimental development, high tension, heat treated steel eyebars, with guaranteed minimum ultimate strength of 105,000 and guaranteed minimum

Longest Eyebar Suspension Bridge (With Span of 1,114 Ft.) Connects Brazilian Mainland to the Island City of Florianopolis. Completed 1926. Eyebars are of high tension, heat treated steel

Ambassador Bridge Over Detroit River With Main Span of 1,850 Ft., Has Stiffening Trusses of Silicon Steel

yield point of 75,000 lb. per sq. in., became available in time to be offered and adopted in 1923 for the Florianopolis Bridge in Brazil (completed in 1926). These eyebars were used as a suspension member, a substitute for the wire cables, at a price that equated the total cost; they made possible, however, a modified type of stiffening truss which yielded greatly increased rigidity at reduced cost. The heat treated eyebars were recommended for a unit stress of 50,000 lb. per sq. in., but this was later reduced to 46,500.

Eyebars Guaranteed by Producer

At the time of this first adoption of the high tension, heat treated eyebars, facilities for full-size tests were limited and privileges of inspection of fabrication were withheld. The engineers were therefore compelled to disclaim responsibility for this material, and the producer furnished a full guarantee to the purchaser. Subsequently the producers waived their policy of secrecy, and removed restrictions on inspection of fabrication. This material suffers from the limitation that the properties of each eyebar depend upon the individual heat treatment which it receives, and the finished eyebars cannot be tested without destruction.

The material has since been used for the cables of two other bridges of the Florianopolis type, both over the Ohio River: the Point Pleasant Bridge (completed in 1928) and the Saint Mary's Bridge (completed in 1929).

In the competitive bidding on the Hudson River Bridge at New York in 1927, the two alternative designs contemplated (a) high tension, heat treated eyebars and (b) parallel wire cables. The wire design won by a margin of $2,000,000, or 20% of the total cost of the cable work, indicating that the high strength eyebars cannot compete with wire cables for extremely long spans. Their cost is about 2¢ a pound above the cost of ordinary structural steel eyebars.

A comparison of the governing physical properties of the important high strength structural steels is presented in the accompanying tabulation.

The metallurgist and the producer can best satisfy the needs of the bridge engineer with respect to these and other high strength structural steels if the following considerations are kept in mind.

1. A high elastic limit is a prime desideratum, since it is the principal factor determining the permissible working stress.

2. The ratio of elastic limit to ultimate strength should not be too high, preferably less than 70%. If the ultimate strength is too close to the elastic limit, a comfortable safety margin is lacking, and relief of excess localized stress through yield is limited.

3. The material should show good elongation and reduction of area before failure. Low values of these test properties are danger signs to the structural engineer.

4. The material should show good working qualities in bending, punching, and drifting tests, depending on the operations to which it is

SPECIFIED GUARANTEED MINIMUM PROPERTIES OF HIGH STRENGTH STRUCTURAL STEEL

	Ultimate Strength	Yield Point	Elongation	Reduction of Area
Nickel steel	90,000	55,000	18% in 8 in.	30%
Silicon steel	80,000	45,000	18% in 8 in.	30%
Manganese steel	90,000	55,000	18% in 8 in.	30%
Mild heat treated eyebars	80,000	50,000	8% in 18 ft.	20%
High tension, heat treated eyebars	105,000	75,000	5% in 18 ft.	—

to be subjected in shop and field and on the form in which it is to be used in the structure. These are important tests to determine the toughness of the material and its safe resistance to injurious effects in fabrication and erection operations.

5. Means of assuring the uniformity of the material and its freedom from injurious internal stresses should be provided.

6. The material must be free from any qualities of brittleness under any conditions of fabrication, erection, or ultimate service.

7. The material should be thoroughly investigated for any limitations of service, to determine its safety for use in tension as well as in compression, in riveted members as well as in non-riveted members.

8. Any new material should be subjected to the most searching investigations, including long-time tests, long-length tests, flexure tests and creep tests, and all information thus secured should be made freely available to prospective users to acquaint them with limitations of safe use and to establish full mutual confidence.

9. The individual bridge engineers do not have the necessary facilities for extended investigation of proposed new materials. It therefore devolves upon the producers, with their metallurgists, their specialized research organizations, and their testing equipment and facilities, to conduct exhaustive investigations of any new material before it is offered or recommended to structural engineers.

10. Because of these greater facilities for thorough research and investigation possessed by the producers, they should properly take full responsibility for any new material developed and should freely back it with their guarantees until it has proved itself safe and dependable through long established use.

11. Metallurgists and producers should thoroughly study the proposed use of any new or special material, and should be prepared to recommend it unreservedly as thoroughly suitable for that use. The individual bridge engineer should be reassured that the material does not possess any unrevealed or tricky properties to unfit it for the full service intended.

12. The producers should avoid any policy of secrecy concerning any special material, and should give the purchaser's engineers unrestricted privileges of inspection and facilities for testing. Any lack of full mutual confidence is an obstacle to the development and adoption of the material.

13. Metallurgists and producers should obviously keep in mind the economic considerations governing the justification of special materials, and should endeavor to meet these conditions in the price at which the materials can be produced.

14. The producers should be in a position to advise bridge designers quite definitely and reliably in advance on the relative price per pound for estimating any special material. Any substantial change in the pound price differential may completely upset detailed economic designs based on the estimate quotations.

15. For maximum cooperation, bridge designers should be kept informed on the various high strength steels available, their complete physical properties, their relative costs per pound, the shapes and sizes in which they are available, their recommended uses and applications, and any limitations on their safe acceptance and application.

Mount Hope Suspension Bridge, Designed By Robinson & Steinman, Received Award for Being the Most Beautiful Bridge Completed in 1929. Copyright Amemya

Magnetic Inspection

achievements to date

By Lewis S. Reid
Chief Engineer, Magnetic Analysis Corp.
Long Island City, N. Y.

CUSTOMARY methods of testing steel to determine physical properties, structure, and chemical constituents are all destructive tests, since in performing them the piece of steel tested is destroyed. Furthermore these tests are made on samples chosen to be as representative as possible of the entire lot; the results obtained from them are assumed to hold true and represent the balance of that particular lot of steel.

The limitations of these tests are well known to metal makers and users. A test or group of tests which can be performed on the entire amount of steel to be used without destroying it or injuring it in any way, has long been the goal of many testing engineers.

Within the past few years this problem of non-destructive testing has been attacked by quite a few engineers. The methods employed may be separated into two main groups.

One main group uses a ray which will penetrate the steel and act on a film to produce a picture. What this method in reality does is to make the opaque steel translucent, so that it can be perceived by the eye and the internal area examined for defects. The most notable example of this method in the commercial field involves the use of the X-ray. However, experiments are being carried on with other rays, notably the gamma rays of radium emanation. A particularly good paper on the application of gamma rays was presented by Dr. Robert F. Mehl last September, at the Chicago convention, American Society for Steel Treating.

The other non-destructive test method consists of producing transient phenomena in the steel and then correlating the characteristics of this transient phenomena to the physical, chemical and structural characteristics of the metal.

The leading example of this group is the magnetic method. Another is the electrical. A third method which has been considered and mentioned from time to time, but on which very little research work has been done until just recently, is the acoustical or sound method.

In the first mentioned method, the transient phenomenon is induced magnetism. Certain characteristics or a group of characteristics of the induced magnetism are measured and correlated to known physical and structural characteristics of the steel. Then upon the reappearance of this set of magnetic characteristics, the physical and structural characteristics are known to be the same as in the standard. Therefore the premise upon which magnetic analysis is based is that, for each particular set

or group of physical and structural characteristics, there is a corresponding set or group of magnetic characteristics and only one.

A non-technical explanation of the theory of induced magnetism will probably aid to a better understanding of the theory and application of magnetic analysis.

A piece of steel is made up of innumerable iron atoms. Atoms are considered to consist of a nucleus and a group of electrons, moving in orbits around the nucleus. Since an electron is considered to be a unit particle of electricity, an electron-in-motion is an electric current. A magnetic field is always associated with a current of electricity.

Normally the electronic orbits in the different atoms are in random directions and neutralize each other. When a low magnetizing force is applied to the steel some of these orbits are oriented so their direction is the same. As the magnetizing force is increased, more and more of the electronic orbits become uni-directional. A point is reached at which no further electron orbits are oriented even after increasing the magnetizing force. This stage is known as "magnetic saturation." The action of these electrons under increasing magnetizing forces, when measured and plotted, produces the "B-H curves." A typical B-H or magnetization curve is shown dotted in the graph. It starts from zero, rises slowly for a time, then rapidly, then flattens off to saturation.

If the magnetizing force is cyclic (such as produced by an alternating current) we get a closed loop, called the "hysteresis loop." A typical hysteresis loop is shown in the graph. In other words, when the magnetizing force is removed the magnetization does not follow back down the original curve; there is a lag. Certain terms used in magnetic science are defined by this hysteresis loop. "A" on the curve represents the value of the "residual induction," while "B" on the curve indicates the corresponding value of the "coercive force."

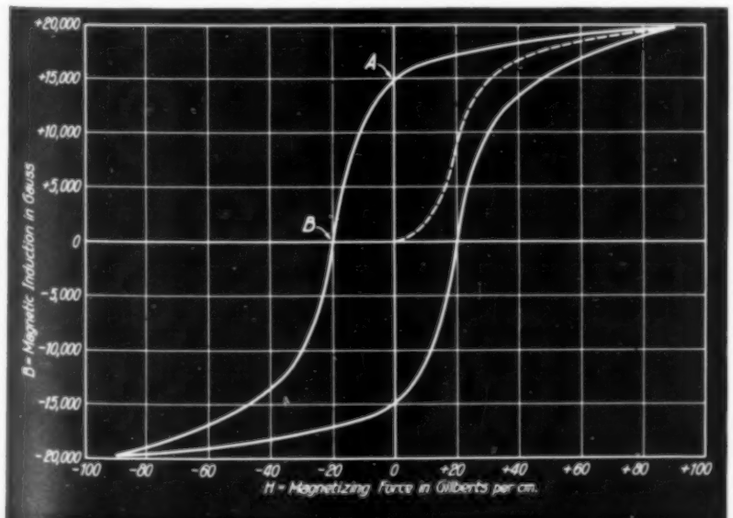
In magnetic analysis, changes in one or several of these different magnetic properties or changes in the relationships between some of the properties are used as a means for discovering changes in mechanical and structural properties of the steel.

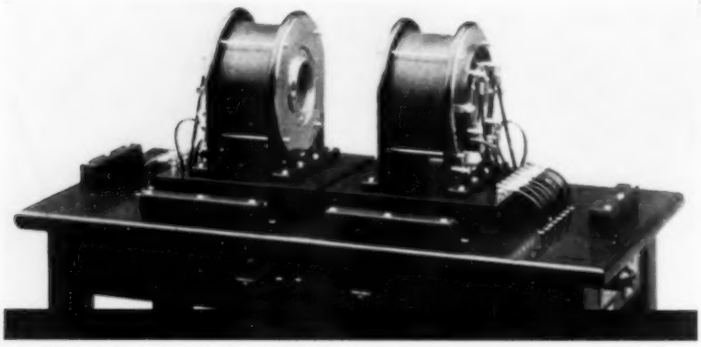
There are two types of electrical current commercially available for producing the magnetic field, namely, direct current and alternating current. The former was the first used; in fact present interest in magnetic analysis can be traced to the pioneer work which was done with direct current by Dr. C. W. Burrows. In addition to working on methods of correlating abnormal mechanical and structural characteristics of steel to various magnetic characteristics, he also devised a method of detecting defects by magnetic leakage.

There are, however, several objectionable features of direct current in this problem. Although it is still being experimented with and in a few instances is being used successfully, the greater amount of work in late years has been done with alternating current. The one great advantage of direct current over alternating current is that it is not limited by lack of penetration.

Alternating current is avail-

Relation Between Magnetism and Its Inducing Force. Dotted curve represents condition during first magnetization. Curved loop represents cyclic variation under alternating forces





Simple Test Set Contains Two Identical Primary Solenoids; Within Each Is a Secondary Coil. Circuits of the secondary coil are set so they oppose each other, and the recorders measure differences in their effects

able commercially in two frequencies; 60 and 25 cycles. Of these two, the one most often used in magnetic analysis is the 60 cycle. Many of the objectionable features of direct current are eliminated by using alternating current.

A number of different circuits can be used and a variety of magnetic characteristics employed as the means for correlation but it is beyond the scope of this article to go into a technical discussion of them. At present it is desired to describe in a simple manner only one of the circuits used and some of the results obtained.

Magnetic fields may be produced by solenoids. The solenoid consists of a hollow cylindrical form on which is found a known number of turns of wire. The product of the number of turns of wire and the amperes of electrical current passing through the coil is a measure of the magnetizing force of the coil. In the primary circuit, two of these solenoids, each wound so that they produce fields of equal intensity, are connected with suitable instruments to regulate and vary the current, together with instruments to show various current and voltage values. Thus, the function of this primary circuit is the production, control and variation of the magnetic field required by the testing engineer.

Wound on sleeves which fit into and are centrally located within the solenoids are smaller coils. These are the secondary or "search" coils. A view of two solenoids is given at the left; within each one is a smaller secondary coil. The two search coils are so connected that their currents oppose each other, and in this secondary circuit is the indicating instrument (in this case a multi-element oscillograph) and some suitable control instruments. An oscillograph is shown in the figure below. It consists essentially of a small sensitive galvanometer by means of which small values of current or voltage may be measured. Attached to the vibrator string of this galvanometer is a small mirror which is illuminated by an electric bulb, or other light source. A light beam deflected by this mirror is caught by a series of mirrors which are oscillated by means of a synchronous motor. Variations in the current being measured increase or decrease the deflection of the galvanometer in a horizontal plane, and cause a corresponding deflection in the ray of light, but the oscillating synchronized mirrors then separate these values in a vertical plane, and the result is a spot of light which travels in a wave form. This wave is seen in the ground glass, pictured in the upper left hand section of the oscillograph box. Some waves are shown on page 44.

What is measured with the oscillograph.

An Oscillograph Is Used To Analyze the Differences In Magnetism Induced In Standard Sample and an Unknown Test Piece

therefore, is the rate of change of magnetic induction. Since this method consists of a comparison (in the sense that a standard piece of steel has been placed in one coil and an unknown specimen in the other), and since the two secondary coils oppose each other in the circuit, the wave form on the oscillograph is really a measure of the difference in the rate of change of the induced magnetism in the standard and the rate of change of induced magnetism in the unknown piece of metal.

Magnetic Condition Visualized

Theoretically, then, if the induced magnetism in both the standard and the specimen changed at a uniform rate throughout the entire cycle and were in phase we would have no current flowing to the galvanometer, and only a straight line of light would appear on the viewing glass or film. As the different conditions in the steel specimen alter the rate of change of induced magnetism, various wave forms are produced by the spot of light. The problem of magnetic inspection, however, is not simple — for besides curve interpretation, the effect of eddy currents at times modifies the set scheme of things. But these extenuating conditions are being gradually modified as greater knowledge of them is being accumulated, and even now there are several commercial installations.

Installations have been of two kinds. One is a laboratory installation in which either small quantities of material are tested or research work is carried on. (A compact equipment for this purpose is shown in the figure.) The other kind is used in production and necessarily meets different conditions and so is more rugged in nature. This test method adapts itself chiefly to material of uniform cross sectional area such as rods, bars, pipe, tubes, sheet and strip, which can easily be threaded through the coils.

Laboratory Set for Magnetic Testing and Inspection. Coils, control equipment, oscillograph and static indicators all in compact set

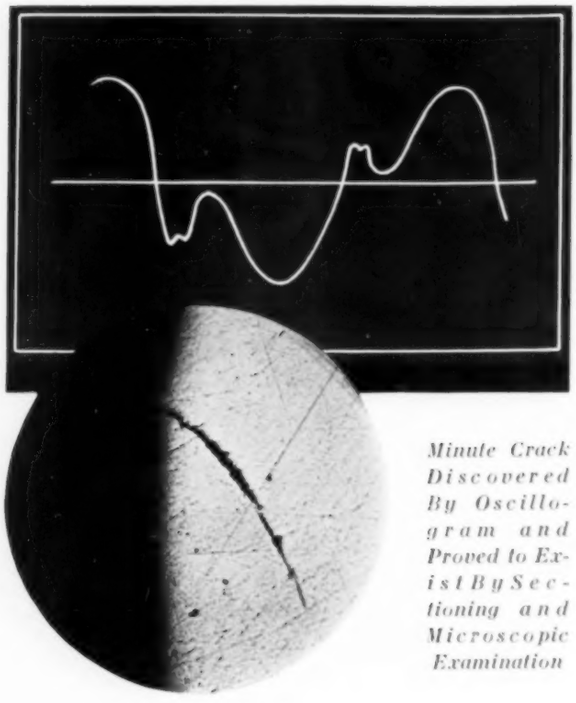
In practice a standard piece of the desired physical properties, free from defects, is placed in one of the coils. Then the material to be tested is run through the other coil and compared to the standard section. Any variation from the standard will show on the oscillograph as a change in the shape or amplitude of the resulting wave.

An instance of the value of magnetic analysis in detecting a difference in chemical composition is shown in the two oscillograms shown at the foot of the next page.

A hundred or more bars of S.A.E. 2320 became mixed with about 1500 bars of S.A.E. 2512. The conventional method of rigidly separating these bars would have been the long, tedious and costly chemical analysis of the nickel content of each bar. They were, however, separated by magnetic analysis in less than three hours.

Another instance where the separation of material of different chemical analysis has been accomplished is in segregating S.A.E. 1020 tubing from S.A.E. 1130-X tubing. Both varieties are extensively used in aircraft manufacture. It is quite important in this industry that these two types of tubing do not become mixed, and magnetic analysis provides a quick test for checking any admixture of stock. Many other instances could be cited where the separation of steels of different chemical analysis by the magnetic method has been carried out, even to the separation of two steels whose analysis differed only in the percentages of the minor constituents.

An oscillogram from another installation, shown herewith, indicates a crack in a bar when compared to a standard known to be free from defects. The photomicrograph shows the crack which was found in this section of the bar



Minute Crack Discovered By Oscillogram and Proved to Exist By Sectioning and Microscopic Examination

when it was cut and etched, a crack that was so small that it could not be perceived by visual inspection.

Strip steel, to mention yet another type, is being analyzed magnetically on a commercial scale.

One installation has been employed in the analysis of the strip from which safety razor blades are made. This equipment detects differences in carbon content, differences in hardness and the presence of inclusions, notably carbide segregations. Another strip steel installation is successfully picking out laminations in the material.

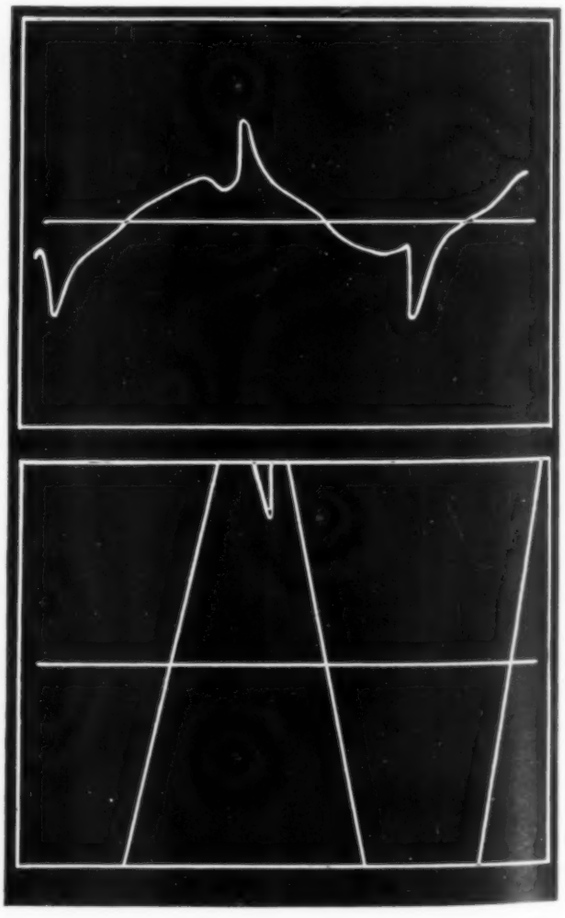
Magnetic analysis method has been applied successfully for inspecting butt welded tubes, picking out burned pipe and weak welds. The method explained in this article, and other methods as well, are being developed for the non-destructive testing of resistance and arc welded joints.

Other methods of magnetic analysis have been applied successfully to the inspection of ball bearing races and to the cross links in automobile skid chains.

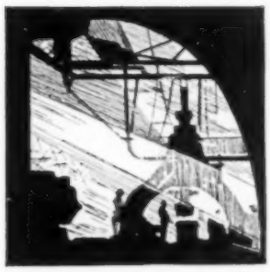
It is obvious, therefore, that in its present state of development magnetic analysis can be applied successfully to a number of steel problems. There are also a number of other problems which cannot be solved by magnetic analysis methods, but there are some that will probably be worked out successfully as the methods are improved and further research work is done.

At the present time each application of magnetic analysis is at first a research problem. Experimental work must be performed before it can be stated whether or not, in its present state of development, the method can be successfully applied to that particular problem. As more correlative data between the magnetic properties and the physical, structural and chemical properties of steel are obtained and improvements made in the circuits, the present field of application of magnetic analysis will undoubtedly be broadened.

Bars of S.A.E. 2320 and 2512, Indistinguishable By Rapid Tests, Give Unmistakable Indications To the Magnetic Tester



Testing Steel for Forging



By Adam M. Steever
Chief Metallurgist
Great Lakes Forge Co., Chicago

PRODUCTION of quality drop forgings requires the procurement of sound steel free from any defects that would endanger the fulfillment of that aim.

Steel, the raw material of the forge shop, is usually specified by the forge shop's customer. Certain of the motor car and aircraft companies purchase their own steel for their forgings, an advantage both to the customer and to the forger. It enables the customer to be sure that the proper steel is used in making his forgings and also insures uniformity of the product as far as the steel is concerned, especially of parts from small forging plants which do not have a laboratory to check the analysis of steel as it comes from the mills.

On the other hand, the drop forge companies benefit by this arrangement because they know that their competitors are using the same type of steel at the same price. Then, too, if forgings are rejected, the large customer who buys and supplies the material can sometimes accomplish more with the steel companies than can the average forge shop.

When the drop forger buys the steel, he specifies "forging quality," which ensures a material that is best suited for his purpose. He is guided by the specifications from his customers, and obtains the analysis specified in billet sizes that meet the purpose for each individual type of forging.

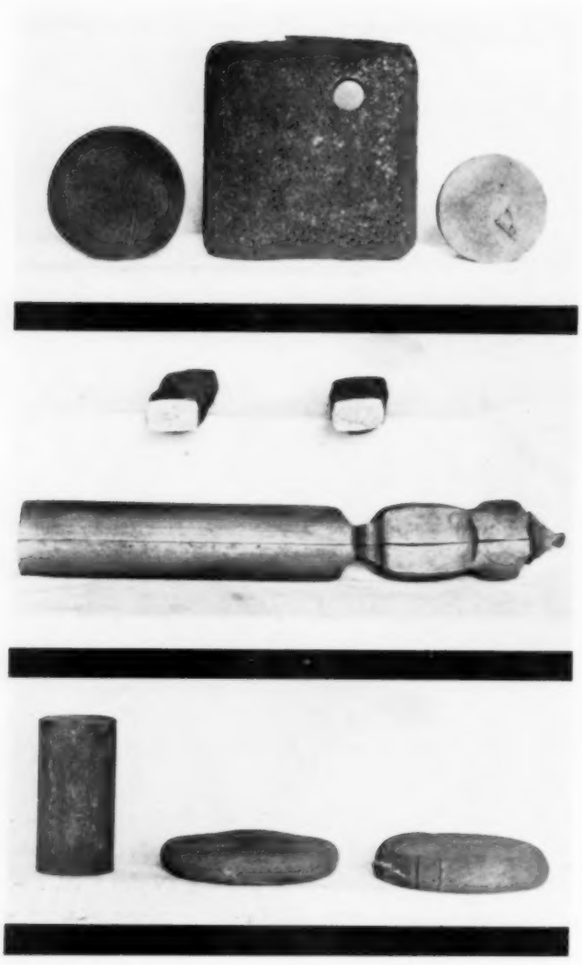
When "forging quality" of steel is ordered, it is expected that the steel mill will furnish material of good quality, free from any defects that would cause rejection of the finished product.

In order to protect himself against defective materials, the drop forger must make a series of tests to make certain the material purchased meets the specified requirements. These tests are made upon receipt of the steel and completed before the material is released for production.

Three factors affect the forging quality of steel. They are, 1. Chemical composition. 2. Surface condition. 3. Its ability to flow freely in all directions without rupture under pressure or impact.

Responsibility for piped, seamy, and otherwise unsound metal rests entirely with the steel maker. Piped steel is usually caused by trying to get too much yield from the ingot. Seams usually result from improper control of pouring and rolling practice.

In the Great Lakes Forge plant all steel is carefully inspected. Upon receipt of each heat of steel, the steel yard foreman inspects a minimum of 20 bars for surface condition, size and multiples. If this inspection shows the material



At Top Are Sectioned Bars Etched for Porosity. Left is satisfactory; center is unsatisfactory; right is piped

At Center Are Bars Forged Longitudinally. Top shows O.K. fracture; bottom indicates effect of surface seam

At Bottom Is Upset Forging Test. Left is the slug used; center is a good upset test; right has edge bursts from surface seams

to be defective he reports to the metallurgist, who in turn takes it up with the vendor and at the same time notifies the shop management that the steel in question cannot be depended upon for production, because it failed to pass this preliminary inspection.

If the material is reported as being satisfactory by the steel yard foreman, the metallurgist approves the report and the laboratory proceeds with further tests.

Incoming steel is piled in such a manner that drillings can be taken with a portable electric drill. Each heat is piled separately and each size of a given heat is also segregated. A laboratory number accurately identifying the heat is assigned upon unloading.

Bars are marked serially for identification as they are drilled. One ounce of drillings is taken from five bars at random from each heat for complete chemical analysis. About one-quarter ounce of drillings from 25% of the remaining bars is taken for carbon analysis, in the event the heat is a straight carbon steel. Care is taken in this work so that drillings are free from impurities such as dirt, cinders and oil. Drilling chips from the first ⅛-in. of the hole are discarded to eliminate the possibility of sampling decarbonized steel.

If the heat is an alloy steel, a complete analysis is made of the first five bars from each heat, and 25% of the remaining bars is tested quantitatively for carbon and qualitatively for nickel (in nickel and chromium-nickel steel) and qualitatively for chromium (in chromium-

vanadium steel). If these preliminary analyses show the steel to be within specification, the heats are approved for production as far as chemical analysis is concerned. If the analyses show the steel is not within the specification, a 100% analysis is made; the results are the basis for either separation or rejection.

Tests most commonly employed for inspecting the forging properties of a lot of steel are: Pickling, forging and upsetting.

Pickling tests are of two classes: (*a*) for surface defects, such as seams, laps and slivers, and (*b*) for internal defects, such as porosity, pipe and segregation. Pickling to test for surface defects consists of immersing short pieces of the steel bars or billets in hot dilute sulphuric acid for 15 min. The acid removes the mill scale and exposes to view and exaggerates any surface defects that may be hidden or filled with mill scale.

For internal defects, some cross cuts and longitudinal sections are examined by sawing and polishing samples from the bars and immersing them for 30 min. in a 1 to 1 solution of hydrochloric acid heated to 150° F.

Forging tests are accomplished by heating short pieces of the bars and forging them along their longitudinal axis into a small bar. They are then nicked and fractured. Minute pipe can be detected upon examination of this fracture. Excessive pipe will cause the bar to burst in forging. Surface seams will open up and sometimes cause the bars to split.

For upsetting tests, short pieces are heated and upset under a hammer. This test is more severe and readily shows up any physical defects the piece may contain.

More elaborate tests are employed before making special forgings which demand maximum physical properties. For these tests the steel is submitted to specific methods of heat treatment.

The Unfinished Span

Etching of Kill Van Kull Bridge
by O. Kuhler

By Arthur S. Reardon
Sydney, Australia
Photos by the Author

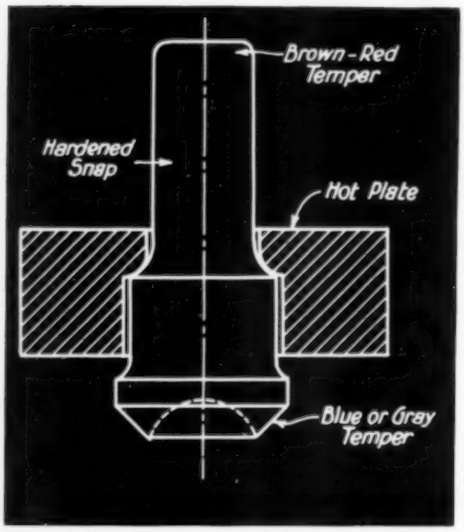
Carburized Alloy Rivet Snaps

IN THE FABRICATION of structural steel work, as well as in general boilershop work, pneumatic riveting snaps have always been a source of trouble. The design of the tool itself is of such a nature that trouble would seem to be an inherent characteristic. Nevertheless attempts to alter the design appear only to result in impairing the efficiency of the hammer — or such is the writer's experience. Consequently, snaps continue to break in the neck and it is accepted as something unavoidable.

Most manufacturers of tool steel have developed alloys which are offered for pneumatic snaps, and for which many claims are made. Many of these steels are excellent and do all that can be expected of them, provided the rivets on which they are used do not exceed $\frac{3}{4}$ in. diameter. But when, as happened on the Sydney Harbor Bridge, the majority of the rivets are $1\frac{1}{2}$ in. and $1\frac{1}{4}$ in. diameter, with an occasional line of $1\frac{3}{8}$-in. rivets with $9\frac{7}{8}$-in. grip, the results are far from satisfactory.

At this point it may be noted, for the benefit of American readers, that this bridge is to provide railway, vehicular, and pedestrian traffic between Sydney and its northern suburbs, a metropolitan region of about 1,100,000 souls, heretofore divided by a deep and winding arm of the ocean, reaching miles inland. The entire project, which includes extensive approaches and subway construction, is one of the major pieces of modern engineering — the largest item being the arch itself. This has a span of 1,650 ft.; it contains about 50,200 tons of steel work, and the contract was let at a cost of slightly over $20,000,000.

The contracting firm, Dorman, Long & Co., agreed to use Australian labor and material wherever practicable. For this reason, extensive and up-to-date fabrication shops (capable of building individual members weighing as much as 120 tons) were erected at the water's edge near one abutment. Plates of both carbon and silicon structural grades up to $2\frac{1}{8}$ in. thick were rolled in the Redcar Works, Whitby, England, but as much of the angles, channels, and other sections as could be supplied by Australian firms were rolled in the Commonwealth. About 1,250 men have been engaged on the steel work under the supervision of Laurence Ennis, director of construction for the contractors — to whom credit is due for many suggestions and encouragement in solving the problems to be hereafter described.



Tempering With Hot Plate as Recommended by Steel Makers Gives Soft Shoulder Which Often Breaks

The situation confronting the heat treater in the workshops for the bridge was this:

1. A special size of head had been adopted for all rivets. As shown in the sketch, all cups of the snaps were $\frac{1}{8}$ in. deeper than the British standard. This increased the absorption of heat from the rivets being driven, and after eight consecutive rivets of large size the snap would be hot enough to set fire to a rivet bag if dropped on it. For this reason, many of the alloy steels tried for snaps developed brittleness.

2. Inspection of the rivets by government inspectors was very severe; the consequence was that the riveters "dwelt" on each rivet much longer than usual in order to avoid rejects.

3. The material used in construction of the large members was a high grade silicon structural steel. Owing to its hardness, this played havoc with the edges of the cup on the snap when it got warm.

4. The diameter of snap shanks ($\frac{7}{8}$ in.) remained the same for all sizes of rivets.

The air pressure on the hammers was maintained at an average of 110 lb. Boyer No. 80 guns were used for the most part.

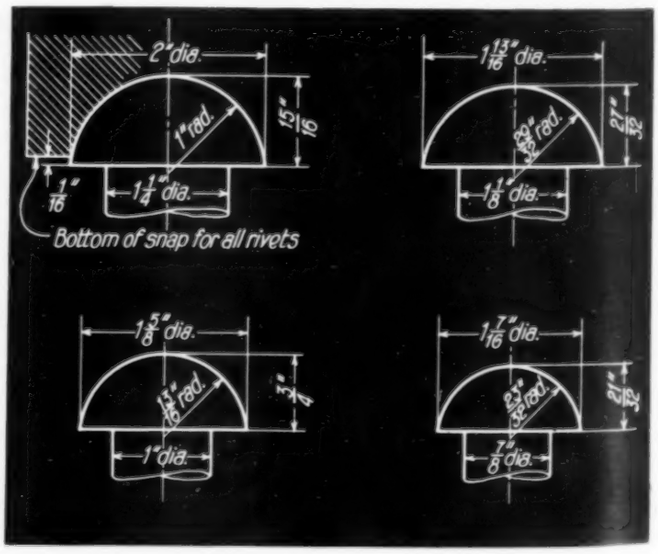
At the commencement of the job, comparative tests were made with all tool steels available in Australia. Straight carbon steels were rejected at the outset as the cups softened before any considerable quantity of rivets had been knocked down. Various water hardening non-tempering alloys were also tried, but 300 was the highest total of $1\frac{1}{8}$-in. rivets done with them before the shanks broke. Several water hardening vanadium alloys gave better results, but not enough to justify adoption. In the meantime most of the tool steel manufacturers trading in New South Wales were supplying test snaps made and treated by themselves, but none of them were able to equal our own results.

Choice fell finally on the chrome-tungsten oil hardening group and ultimately a grade of the following analysis was adopted. The chemical data are as supplied by the manufacturer.

Carbon	0.38 to 0.45%
Manganese	0.25% max.
Silicon	approximately 0.7%
Chromium	1.10%
Tungsten	2.5%

Heat treatment suggested by the makers of this steel was to heat to the range 1,550 to 1,830 F. and quench in oil; then temper by heating from the center in a hot collar (as shown in the sketch) until brown-red at the point of the shank and blue or gray at the cup. This tempering practice was suggested by all

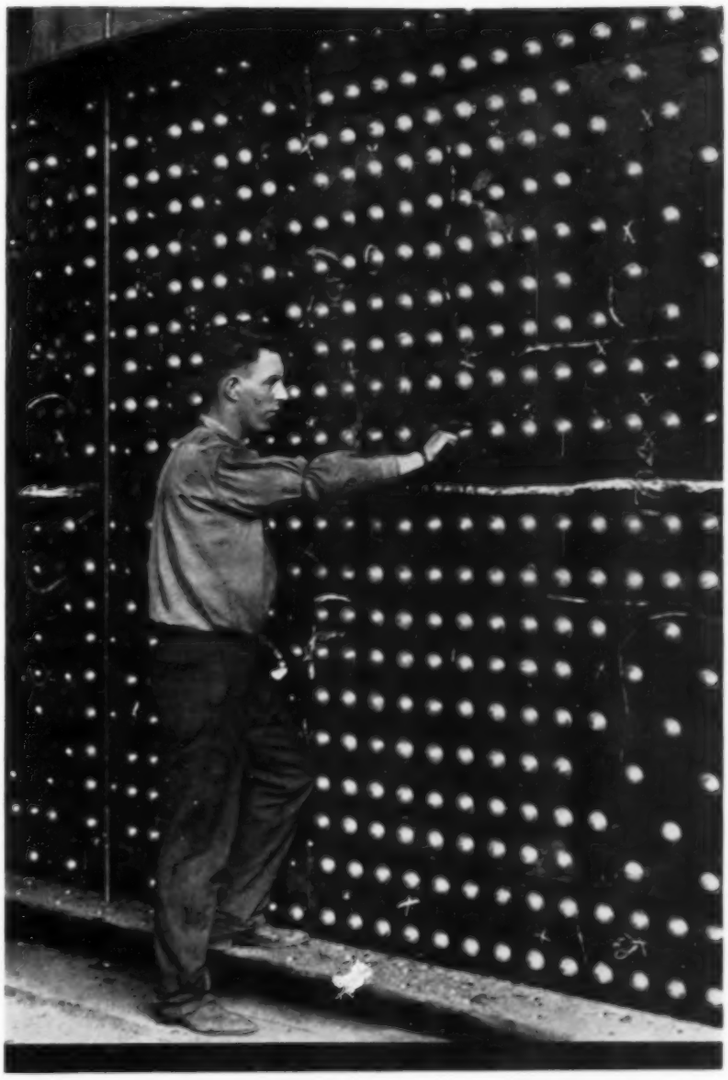
Oversized and Countersunk Heads Added Difficulties



steel makers without exception.

In actual practice, we established very conclusively that the best results were obtained by using the high heat (1,830° F.) for hardening and afterwards tempering to a purple all over. The suggestion that the snap should be tempered much lower in the neck (where it came in contact with the hot plate) was the most fruitful cause of breaking that we encountered.

For a little more than a year this steel and this method of heat treating were adhered to, and performances up to 8,000 rivets per snap were not unusual. Then, for no reason that was apparent at the time, all of the new snaps began to fail. Within a few weeks the average was 35 rivets per snap! No conscious variation in heat treatment had been made and the cause of the trouble was sought elsewhere.



By this time the gun barrels were showing signs of wear. It was suspected that slackness of shanks was the cause of the trouble. As it was not possible to get the barrels closed in Australia they were ground out, and the shank of the new snaps increased slightly to suit. This made practically no noticeable improvement in the performance.

Furnaces were then installed fitted with pyrometers and a strict check of all heats was taken, but this brought no improvement. Independent treatment by the maker of the steel gave no better results, nor were they improved in any way by reasonable variations in the hardening or tempering heats.

It was observed that the fractures showed an increased grain size as compared with the original samples of the steel, and also that the snaps were coming through considerably softer, as disclosed by the file test. These things, coupled with the obvious increase in brittleness, led us to conclude (in the absence of any direct laboratory tests) that the silicon content in the steel was incorrect. When it was suggested to the maker's representative that the silicon had been increased, he strenuously denied it, and adopted the ancient expedient of "blaming the heat treater."

An independent chemical analysis was then obtained which gave silicon 1.0% (in place of the original 0.7%). We still feel that herein lay the cause of the trouble, although this feeling cannot be definitely proved.

By this time the snap question had assumed a very serious aspect and we were in the position of having to start all over again. It must be understood that no tool steel is made in Australia and to get steel from over-seas or to get alterations made in its chemical content is a matter of at least six weeks. Other steels avail-

able on the spot had been tried at the commencement of the job, and were not considered satisfactory by any means. The only thing to do was to attack this worrisome problem from a different angle.

After some thought the writer decided to try the possibilities of a case hardened nickel steel. Accordingly a dozen snaps were made from a 3½% nickel steel. It is interesting to record that several of the original 12 were in use for a year!

From then on various grades of nickel steel were tried and finally the chrome-nickel type came in for consideration. The improvement shown by this type was so marked that ultimately a steel of the following composition was adopted. (Again the analysis quoted is that supplied by the manufacturers.)

Carbon	0.12% to 0.18%
Silicon	0.30%
Manganese	0.30% to 0.50%
Sulphur	0.035% max.
Phosphorus	0.035% max.
Nickel	4.0% to 4.5%
Chromium	1.0% to 1.4%

Heat treating practice adopted for this steel has been to carburize for 7 hr. at 1,690° F., and cool in box. Remove from box and give regenerative quench from 1,620° F. Reheat and quench from 1,400° F., water being used for both quenches.

Carburizing material is an ordinary commercial grade with hard wood charcoal base. It was mixed in the proportion of ⅓ new to ⅔ used; average cost of material was one penny per snap. The average case depth obtained was $\frac{3}{32}$ in.

Carburizing boxes were made of ½-in. scrap steel plate, of a capacity to hold 24 snaps. The lids were made with a flange to fit over the sides of the box and were sealed with fire-clay. The whole was turned over before placing in the furnace. The weight of the box was sufficient to keep it down on the lid and render it quite efficient as a gas container. Average life of carburizing boxes was three months.

Barium Chloride Coating Applied

In order to avoid scaling during heating, and thus retain the correct size in the shank, the snaps were coated with a water solution of barium chloride. It was applied with a brush to the warm snap on removing it from the carburizing box. This method of protecting the surface proved very effective.

Fifty-six rivet squads were thereafter kept supplied with all sizes of snaps made of this chrome-nickel steel, and the estimated breakage, at a liberal estimate, was 2%.

Possibly our most remarkable achievement has been with snaps for flat countersunk heads. Even when the snaps for button heads were standing well when made of the original chrome-tungsten steel, snaps for countersunk rivets were never wholly satisfactory, but after adopting the chrome-nickel case hardened variety we did not have one break for a period of 18 months!

Practically our only trouble in the early days was the tendency of the point of the shank to collapse. This was overcome by chamfering the point down to ¾ in. diameter, the same size as the gun plunger.

Apart from the improved results obtained from the snaps a remarkable saving in steel costs was effected.

When the snaps have been in use on some 500 rivets the cup edges show a slight burr. This is removed in the lathe and the snaps are returned to service. By the time 2,000 rivets have been put in, the snap becomes slightly shallow. They are then annealed, re-cupped and again carburized and hardened.

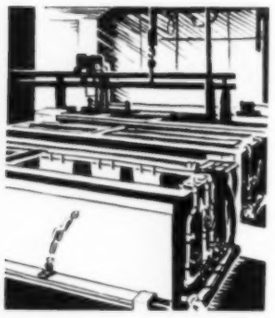
Re-carburized Snaps Did Well

Three re-cuppings is the average before the snap becomes unfit for further service and by that time they have put in upwards of 8,000 rivets. In re-treating no attempt is made to confine the carburizing to the re-cupped end nor have any ill effects been noted from the repeated hardening.

While the results described in these notes may be somewhat unorthodox, they represent something which was done to solve a real problem which was holding up a very important piece of bridge construction. Our resources were somewhat limited, but we feel that the ultimate solution was as good as could have been expected even though we did not have at our command facilities for the experimental work which would have been more than justified by the size of the job in hand.

Sydney Harbor Bridge Was Erected from Crawler Cranes on Top Chord

Chromium Plating Technique



By Robert D. Zimmerman
Ingersoll-Rand Co.
Phillipsburg, N. J.

CHROMIUM plating, as done by Ingersoll-Rand Co. at the Phillipsburg (N.J.) plant, is controlled by the Metallurgical Department and its activities are directed exclusively toward the application of chromium to the surface of metal objects for improving their resistance to abrasive wear. This class of work is known to the trade as "hard" plating, which does not mean that the chromium is any harder than when used for decorative or bright plating, but simply that it is applied to provide a hard surface. The objects plated include various parts which enter into the product manufactured and also many shop tools and fixtures.

The customary residual thickness of plate is 0.002 in. ("residual" meaning the thickness which is on the part when it goes into service). Sizing by grinding is usually necessary, and in such cases an additional thickness of 0.002 in. is applied. In a few parts the residual plate is as thick as 0.035 in. Compared to the few minutes required in bright plating, such thicknesses require long periods of time—an hour (minimum) being required to deposit 0.001 in. on external surfaces, while as much as twice this time may be required for the lining of holes.

Chromium plate is applied by us directly to the metal from which the article is made. Under-plates of copper and nickel (used in bright work) are omitted because they are considered both unnecessary and undesirable; they are not required for bonding nor for finish and are undersirable because they are soft. Chromium is inherently brittle, although in moderate thicknesses not as brittle as commonly supposed. However it is considered best to provide comparatively hard backing when localized pressures of high intensity are likely to be encountered. For this reason if it had been customary to harden a certain part, this hardening is done even though the part is now plated.

A good commercial grinding job on the article to be plated insures a satisfactory finished surface for most mechanical purposes. A satisfactory bond sometimes requires mild sandblasting of the ground surface, but even on such surfaces the plate is fairly bright if it is not more than 0.001 in. thick. Heavier plates come from the bath steel gray. In general, of course, a plated surface is not as smooth as the surface upon which it is laid. It is especially important that this fact be considered when parts do not require grinding after plating. Even fairly bright chromium plates, which feel smooth as they come from the bath, will cause much less rapid wear on rubbing surfaces if the plate is lapped before being put into service. That the plate be smooth and uniform is, of course, es-

sential but the lustre usually associated with chromium plate is unnecessary.

While considerable variation in thickness might not be noticeable in thin decorative plate, it is a characteristic of electroplates that these variations are accentuated as the time of plating increases. Any marked tendency toward irregularity in rate of depositing of a heavy plate would mean the addition of considerable time in the bath to insure sufficient chromium on points of slowest rate of deposition.

To insure a uniform rate of deposition we have discarded the customary flat anodes, and use conforming anodes exclusively. Our equipment and methods therefore create something which differs considerably from the usual conception of electroplating. Instead of visualizing the plating of an object as suspending it in an electrolytic solution tank by means of wires or hooks, we more properly think of the operation as "setting up" the object as part of an electromechanical assembly and then making this a part of a larger assembly which includes the tank. Equipment and methods at Phillipsburg are such as to facilitate such operations.

The plating plant consists of two independent units, the first one installed being a 100 gal., 1,000 ampere, and the second 500 gal., 2,500 ampere capacity. They are both United Chromium outfits and each includes six tanks in the following order:

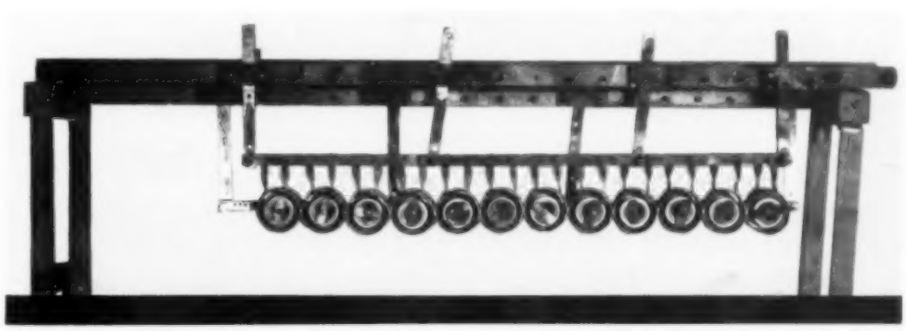
Tank	*Unit No. 1 (100 Gal.)*	*Unit No. 2 (500 Gal.)*
1	Hot water rinse	Hot water rinse
2	Chromic acid cleaner	Alkali strip
3	Alkali cleaner	Alkali cleaner
4	Cold water rinse	Cold water rinse
5	Plater	Plater
6	Plater	Chromic acid cleaner

All tanks are of steel or Armco iron. Plating and chromic acid cleaner tanks have a lead lining and are provided with automatically controlled steam coils giving a uniform temperature of 113° F. (45° C.). This permits 24 hr. or "over week end" operation without the continuous presence of an attendant.

The intermediate rinse tank used to recover solution drag-out in many bright plating plants has been purposely omitted since, due to the longer time required for the heavy plates, the chemical recovery would not justify the risk of contamination from re-used solutions.

An exhaust system is provided for the chromic acid cleaning and plating tanks and electrical connections are provided on all tanks except the rinses. Bus bars serve one end of the small tanks and both ends of the large ones. Spring clips are mounted on bus bars at tank ends to receive the "composite bus bar" spanning the tank and to which the work is suspended. These composite bus bars are composed of three parallel bars to which work fixtures and anodes are bolted, work to center bar, and anodes (in halves if necessary) to the outside ones. A close-up of this bar is shown in the figure. The receiving clips on the tank ends are so arranged that by merely lowering the loaded composite bar into them the proper polarity is obtained — that is, the work is made negative in plater and alkali cleaner, and charged positive in the chromic acid cleaner and strip. Air hoists of Ingersoll-Rand make are mounted on trolleys over each line of tanks to handle work.

A special yoke bar has been devised for mounting two composite bars in tandem when long pieces are to be plated. Shorter yoke bars are provided to supplement the strength of the composite bars when very heavy work is in the tanks. The photographs taken just before closing the floor around the 500-gallon unit, show the piping and electrical details.



Work-Hold Fixtures Are Supported From Central (Lower) Bar. Conforming anodes are held from two outside (upper) bars

Piping and Electrical Connections to 500-Gal. Tanks. View before replacing floor. Note spring clips on tank ends of proper polarity for receiving composite bus bar

Shops are instructed to send only work which has been thoroughly cleaned to the plating room. Any traces of rust are first removed with abrasive cloth and if any trace of grease remains, the parts are thoroughly washed in gasoline. Cast iron or case hardened steel pieces are sandblasted.

It is only after these preliminary operations that the parts are allowed to pass through the various cleaning operations which are a part of the plating procedure itself. In this manner the electric cleaners are contaminated very slowly. Blistering may be expected when work is not properly cleaned.

Following is the path of a typical steel job: After being mounted on the composite bus bar the work is first immersed in the electric alkali cleaner (at a temperature just under boiling) for approximately 15 min. The tank acts as anode. Desired voltage is six, but it may be the same as that on other work in the plater at that time. If this voltage is low the time is lengthened.

Work is then rinsed in cold running water. Pumice stone is used if necessary to remove "water breaks."

The anodes are then assembled, attached to the composite bar and placed in proper relation to the work, care being exercised to prevent their rubbing over the cleaned surface to be plated. The entire assembly is then immersed in the chromic acid cleaner (at about same temperature as the plater) for about 3 min. Here the work is made anodic (positive) and the voltage is usually the same as for plating.

From the chromic acid cleaner the work goes directly to the plater without water rinsing. In adding to a previous plate about 20 min. is used in building up to the plating voltage, otherwise the full plating voltage is applied immediately.

After plating the work is given a cold water rinse. Large work is dried by a hot water rinse; small pieces are carefully dried in sawdust.

Finished work which is only plated locally (for instance, a steel shaft having a wheel-fit built up) is given a dip in the hot alkali tank instead of being dried, and not rinsed, so as to prevent rust on unplated portions. This dip, minus rinse, is also used for work already cleaned which must wait several hours before reaching the plating tank. It is also a very convenient way of furnishing temporary protection to work holding devices. Work so treated is rinsed in water before being placed in the chromic acid cleaner.

Anodes are of a great variety of shapes and sizes, although the largest percentage are cylindrical. They vary in diameter from $\frac{1}{16}$ in. to 21 in., and in length up to 48 in.

Considerable thought has been given to the details of construction in order to secure rigidity, ample current carrying capacity and

proper "gassing" action. They are all fabricated on the premises of commercial sheet lead ($\frac{1}{16}$ and $\frac{1}{8}$-in.) and pipe. This is much easier to work than the 6% antimonial lead and it resists deterioration satisfactorily. Some cylindrical anodes 1 in. diameter by 1 in. long, made of $\frac{1}{16}$ in. lead, have been used 300 hr. (150 two-hour immersions) and are in excellent condition.

Supporting straps of steel are encased to a few inches above the solution level in $\frac{1}{16}$-in. sheet lead. All lead joints are made by "burning" with an oxy-acetylene torch. These burned joints provide a liquid tight seal for protecting the steel "backbone" and insure good conductivity between anode and strap.

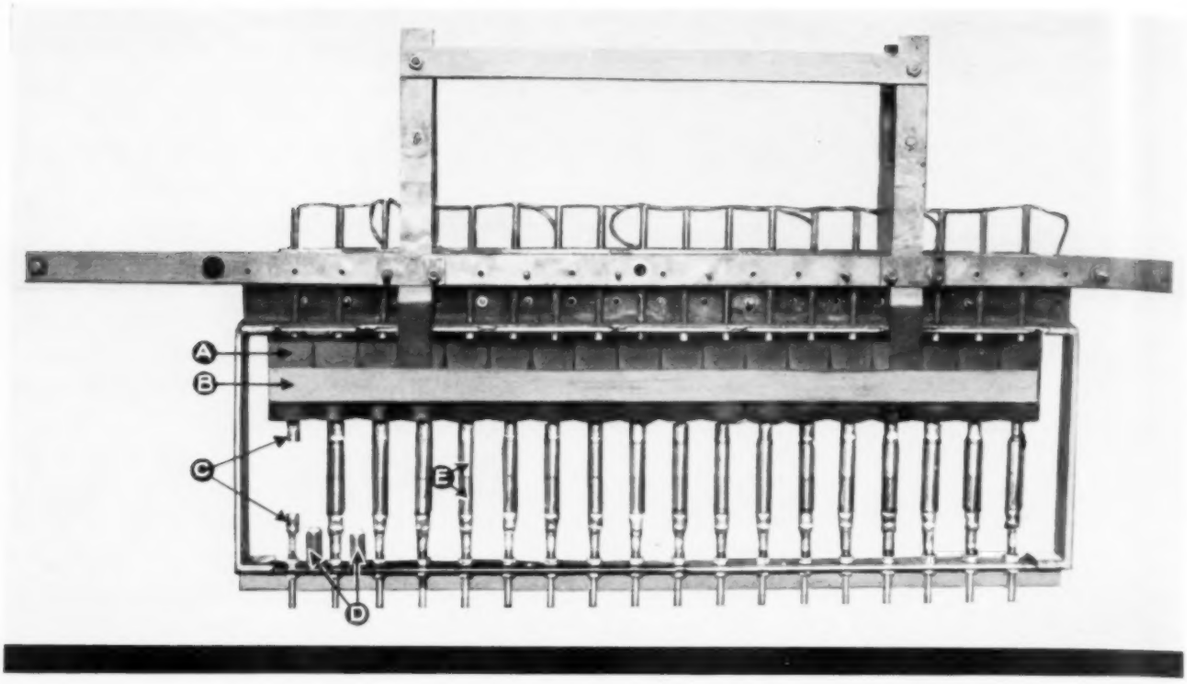
About the only problem arising in the design of flat anodes for plating flat surfaces is to provide the proper "bulge" so the center of the anode is nearer the work than at the edges in order to give uniform current density. A few cylindrical anodes for such work as crankshafts must be made in halves, each half with a separate hanger. Others are made in two parts so as to permit "closing in" to accommodate various diameters.

One type of anode has the straps burned on, while the other consists of a split cylinder with current carrying strips of lead burned on. The latter type is supported in separate lead-sheathed hangers with hook ends. By using different hangers this type may be used vertically, horizontally or at any angle. When used in multiples to obtain length, one hanger supports the adjoining ends of a pair, thus reducing the number of hangers required. On all anodes of any appreciable area a number of small holes, about $\frac{3}{16}$-in. diameter, are burned in the surface to facilitate escape of gas.

To insure maximum tank capacity and minimum anode cost it is obvious that the anode selected for a given job should be the one which gives the minimum spacing from anode to work. However, as the spacing decreases the variations in current density (and consequently thickness of plate due to slight inaccuracies in spacing) are magnified. The spacing we use at Phillipsburg varies from $\frac{3}{4}$ in. on $\frac{1}{4}$-in. external diameter work, to $1\frac{1}{2}$ in. on 6-in. diameter or larger. These distances have been found satisfactory when used with anodes made to a readily attainable degree of accuracy and set up with reasonable care.

It may be noted that at these spacings, 3.5 to 4.5 volts are usually required to give the 2.5 ampere per sq.in. at which the steel is usually plated. Lower current density, of course, means slower plating. Excessive current density results in a rough and non-adherent plate such as shown in the figure on page 58. Sandblasted surfaces require a slightly higher voltage, especially in starting. Cast iron is usually run at 4 amperes per sq.in.

For long cylindrical pieces plated horizontally a narrower spacing than customary is sometimes used to prevent pitting along the bottom. Sufficient circulation of solution is induced by this means to wash away the gas bub-



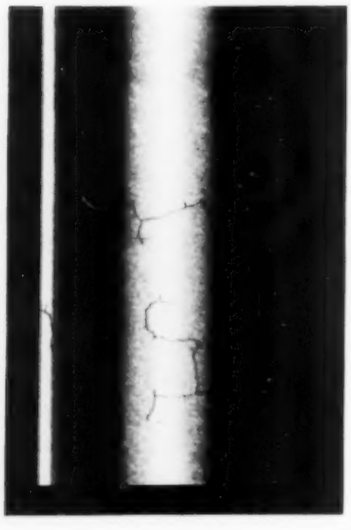
Fixture for Plating 36 Pins. A pair is held between upper and lower cups. "A" is a conforming anode

bles which form along the bottom of the work.

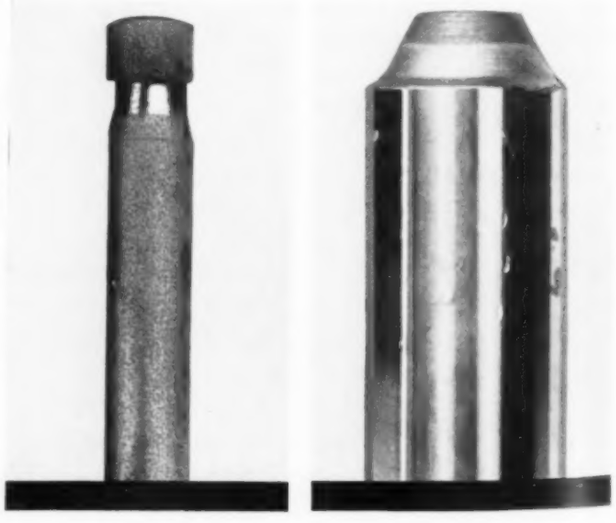
Anode spacing is sometimes decreased when plating up to a shoulder or face by turning its edges inward to counteract "robbing" by the face.

Work racks consist of assemblies of cold rolled steel members fastened together by bolts. This part of the equipment corresponds in principle to the familiar "Mecanno" sets for boys. Being always used on the cathode side of the circuit, these racks need no protective covering. Due to the slight frost of chromium deposited upon them they usually do not rust. Steel is, of course, not the best material to be used for an electrical circuit in a process which requires considerable current. However, the cross sections required for mechanical rigidity are usually greater than required electrically.

Setting up consists of bolting the work racks to the composite bus bars, bolting the work in place and fitting the anodes. As men-



Avoidable Defects. At right the plate blistered because the steel surface was improperly cleaned. In the center is a rough, nonadherent plate due to excessive current density. Note the "tree" at end. At left are grinding checks



tioned before, the latter are not actually fastened in place until the work assembly has been in the alkali cleaner. The surface to be plated is set in a vertical plane whenever possible, since in this position it is easier to get rid of the gas.

If any portion of the work within effective range of the anodes is not to be plated, it is protected with lacquer or with sheet lead. If lacquer is used it is applied after electric alkali cleaning. Since lead shields need not be liquid-tight, such protection is usually a piece of sheet lead wrapped about the work (wired in place if necessary). For keyways a piece of lead sheet is hammered or pushed into place. Where the use of lead is impracticable, lacquer is resorted to.

Production fixtures are two kinds *(a)* those for plating a number of similar parts at the same time and (*b*) those for plating a number of identical parts.

In the first class come the special racks for holding miscellaneous gages and shafts. A variety of anodes is provided, several of each size in quite a range.

For handling large quantities of identical parts composite fixtures are constructed. Two of these are shown in the illustrations. Some of these have capacities of 200 pieces. They consist of multiple work-holders and anodes, so arranged as to permit assembly to the composite bus bar as a unit. Sometimes they are of the single purpose type, but when possible they are built so that by insertion of spacers or by other minor adjustments more than one job may be plated. For instance, pins of various lengths may be plated in a fixture such as the one shown on the top of the opposite page.

Special attention is given to provide for rapid loading and unloading. Spring actuated work holders are used whenever possible.

Some of the anodes are fixed in position — they are not removed from the composite bus bar. In these the work-rack assembly and the work is positioned with reference to the anodes instead of vice versa.

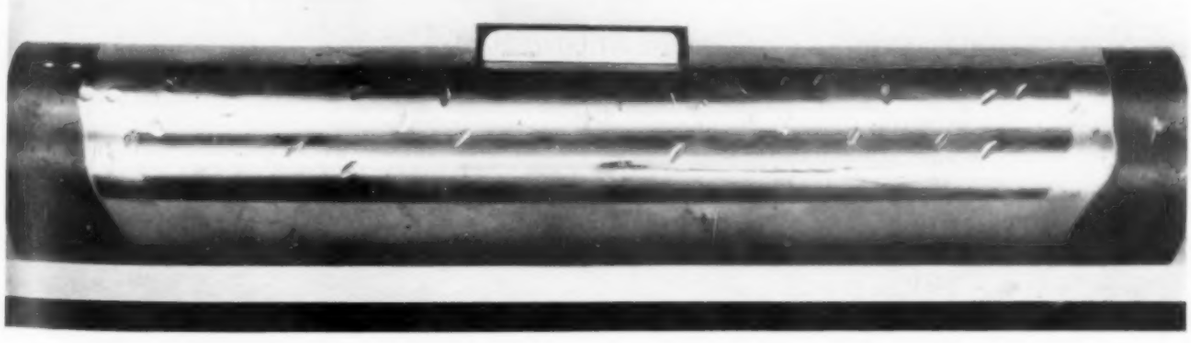
In another type, such as shown on page 58 the anodes raise as a unit to clear the work, and then lower into plating position after the fixture has been reloaded. These are used on jobs where electric alkali cleaning may be omitted. If this cleaning is necessary, the raised position is such as to bring the anodes above the solution level. When the weight of the anodes is sufficient to justify such an arrangement, the anodes are arranged for raising and lowering with the air hoists.

In all designs efforts are made to insure uniform current distribution and a minimum loss of chromium by useless deposition upon the fixture. Joints which come below solution level are made by welding wherever practicable.

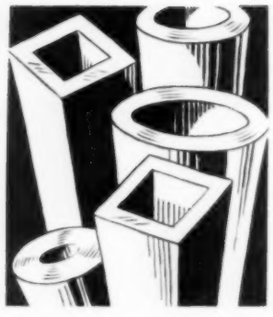
Referring to the half tone *A* indicates the anodes, burned to anode bar *B*. These are in the raised position, clearing the work. *C, C* are work holding cups, the upper being spring loaded, the lower being adjustable for different length work by a long thread and double nut. *D, D* are two pieces to be plated, ready to be inserted between *C C*; *E, E* represents a pair in place. Flexible wires, to insure uniform distribution of current, may be seen soldered to the top ends of the vertical work-holding plungers.

The usual amount of *(Cont. on page 102)*

A Properly Made Chromium Plate, Even as Thick as 0.007 In., Is Not Brittle Under Hammer Blows



By G. P. McNiff
Assistant Vice President
National Tube Co.



Tubing of various sizes and alloys

SEAMLESS tubes have some outstanding differences from tubes produced by other methods of manufacture. First is the obvious fact that the tube is without seam or weld at any point, thus assuring a product of homogeneous section throughout. Second is the fact that none of the other processes now used permit of the variation in choice of analyses and physical properties of material.

In general the lap and butt weld processes are almost completely confined to low carbon material in the range of 0.08 to 0.12% carbon. The later-day electric welding processes have sometimes permitted carbons running as high as 0.30% and even slightly more. In the seamless process no such restrictions exist. Material is being fabricated today into seamless tubing with carbon content ranging from 0.10% to 0.60% and even 0.70%. In addition to this, a large range of alloys is now available, not only in the usual S.A.E. steels but also the stainless alloys which are capable of being made into tubing by this method. Considerable quantities of 18% chromium 8% nickel tubing, as well as some of the intermediate grades of chromium steels, going as low as 4 to 6% chromium, are being quite widely used in the oil cracking and refinery processes.

It might be of interest to give here some idea as to the physical properties to be expected from hot finished seamless tubes. In general it can be said that for the same carbon content or analysis, the physical properties of tubular material will correspond in general with those of equivalent solid rolled or forged sections. The only variable which alters this comparison to any degree is due to the fact that the inside diameter permits air to circulate and thus cool faster than a solid section does. As might be expected, a direct measure of this variable can be found by considering the wall thickness.

In this connection refer to the first diagram, which shows the effect of wall thickness on the physical properties. It shows the relation of increasing wall thickness plotted against the percentage change in tensile strength and yield point. Physical properties for each wall thickness are referred to those of a tube with ⅛-in. wall as 100%.

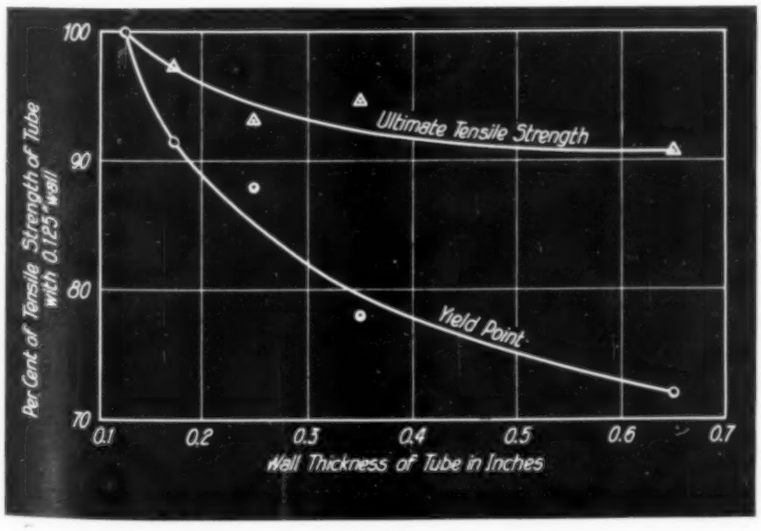
Tubing which was tested to get the data for this diagram had the following analysis: Carbon 0.30 to 0.40%, manganese 0.40 to 0.65%, sulphur under 0.045%, and phosphorus under 0.04%. The average tensile properties of such a hot rolled seamless tube with 0.125-in. wall will be: Tensile strength, 77,000 lb. per sq.in.;

yield point, 50,000 lb. per sq.in.; elongation in 2 in., 44%; and reduction of area, 35%.

This matter is of importance, for it is not generally realized that the wall thickness is of considerable importance in determining the tensile properties of a tube of given composition. If it is realized, however, that a range of wall thicknesses from ⅛ to ⅜ in. is not at all uncommon, and that such a range bears a very similar relation to a range in bar stock of from 1 to 5 in. diameter, this question of variation in physical properties can be better appreciated.

From the figure it is seen that the effect of a given change in wall thickness on tensile strength is greater for the light walls, and becomes less effective as the walls approach the heavier sizes. This same tendency is shown with respect to the yield point, but the change is much greater than in the tensile strength. This is borne out by general experience in heat treatment and annealing; quenching increases the elastic ratio very greatly while annealing decreases the ratio. The thin-walled tube can be considered as having had an air quench with respect to the slower cooling (similar to an anneal) of the heavier wall section.

Relation Between Tensile Properties and Wall Thickness of Hot Rolled Seamless Steel Tubes. Basis is tube with 0.125-in. wall; ultimate strength = 77,000 lb. per sq.in., yield point = 50,000 lb. per sq.in.



While such hot finished material does not permit one to choose physical properties that can be obtained in cold drawn material, it would probably be well here to give some idea as to the physicals that can be obtained from the former. As has just been shown, they will vary to a certain extent depending upon the tubular section. However, eliminating this variable and taking a tube of normal size, the following physical properties will obtain for the analysis given:

Soft grade 0.10 to 0.20% carbon, conforming to S.A.E. 1015, in the as-rolled condition will have an average ultimate strength of 55,000 lb. per sq.in., a yield point of 35,000 lb. per sq.in. and an elongation of 40% in 2 in.

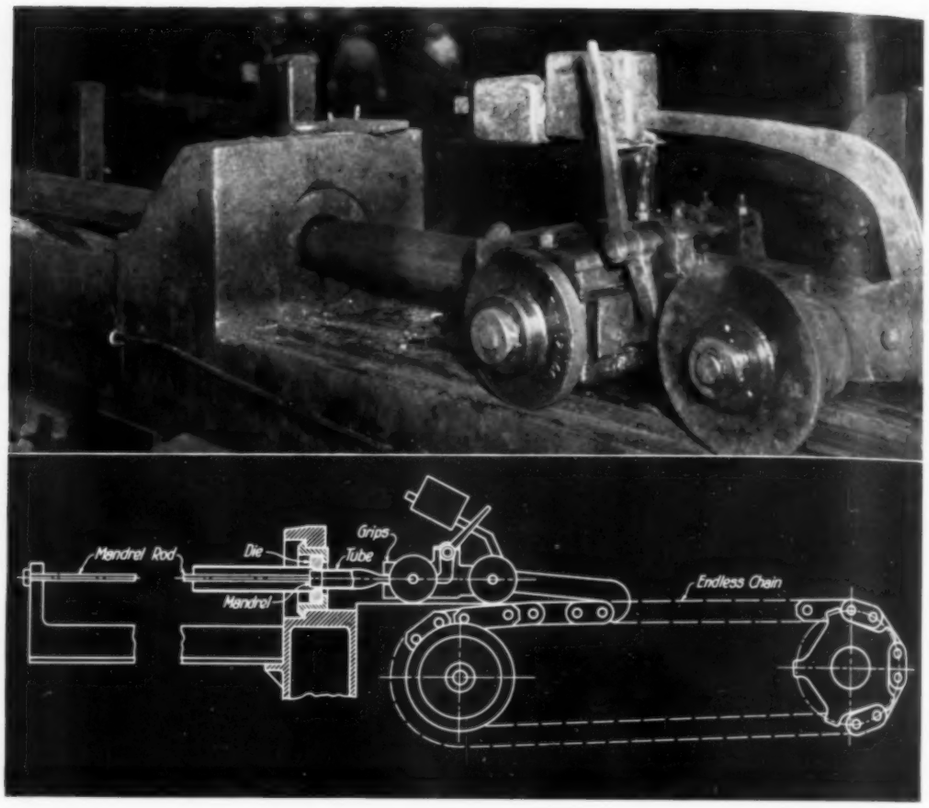
Medium grade, 0.20 to 0.30% carbon, or S.A.E. 1025, will have an ultimate strength of approximately 60,000 lb. per sq.in., a yield point of 37,000 lb. per sq.in., and an elongation of 35% in 2 in.

Medium hard grade, S.A.E. 1035, or 0.30 to 0.40% carbon, can meet an ultimate strength of 70,000 lb., a yield point of 40,000 lb., and an elongation of 30% in 2 in.

Medium Manganese Tubes for Strength

It will be noted that these carbon contents do not furnish the maximum physicals that are desirable for some uses, such as line pipe. It was therefore found expedient by the National Tube Co., in order to meet this increased demand and yet eliminate any of the detrimental effects of carbon on the welding properties, and also to maintain a maximum of ductility in the material, to substitute manganese for the carbon. With this combination a range of physical properties without any detrimental effects on the welding can be readily obtained.

For example, by the judicious use of manganese, the physical properties of S.A.E. 1030 can be obtained with a carbon content of approximately 0.20%. A definite increase in the manganese



Pointed End of Tube Is Thrust Through Die, Mandrel Fixed Inside, Grips Adjusted and Hooked Into Endless Chain, Which Draws Tube to Slightly Smaller Dimensions

content with only a slight increase in carbon produces material with tensile strength averaging in the neighborhood of 70,000 to 80,000 lb. per sq.in. At the present time, we do not recommend the use of higher carbon than 0.35% when the joints are to be made by welding. However, as the ability to weld higher carbon content material is developed, it will be possible to manufacture material with much higher tensile strength. This is in fact now being done in drill pipe and casing, where tensile strengths of 95,000 to 100,000 lb. per sq.in. are common.

The development and the availability of such material with high physical properties has, in our opinion, created a situation of which cognizance must be taken shortly if the benefits which are derived from the use of such material are to be retained. I refer to the tendency to decrease the thickness of the pipe wall and depend upon the higher tensile strength for service. This is dangerous, in our opinion, as the resistance to oxidation or corrosion is more or less a function of the wall thickness rather than tensile strength. Undoubtedly the next few years will find considerable replacements being made in a number of the lines with very light thickness of walls which have so far been laid.

There is, of course, the answer that "Coating will take care of such a condition." However, to our knowledge there has not been developed at the present time a coating of sufficient permanence and efficiency to prevent corrosion absolutely. This contention is borne out when it is remembered that at the present time nearly all parties interested in long pipe lines are searching for a permanent and efficient coating. Until a perfect coating is developed, the permanence of a line is going to depend considerably upon the thickness of the pipe used, and engineers in designing such lines cannot expend too much thought in determining the economical thickness which should be utilized.

18-8 vs. 6% Chromium Tube

Passing on to some of the alloy steels, it would probably be interesting to give some of the physical properties to be obtained from them with reference particularly to the "stainless" variety. The alloy being most generally used at present to resist corrosion around oil refineries contains 18% chromium and 8%

nickel, with a very low carbon content. This tubular material as furnished, heat treated, will have approximately the following physical properties: Ultimate strength, 85,000 lb. per sq.in.; yield point, 35,000 lb. per sq.in.; elongation, 50% in 2 in.

The steel, being austenitic, possesses some very valuable properties. In spite of its high tensile value, it may be fabricated cold to almost the same extent as a mild carbon steel. It must be borne in mind, however, that the increased tensile strength requires additional power for manipulation.

Particular properties of this material which recommend it most readily to the oil cracking industry, are — first, its resistance to corrosion; second, its resistance to oxidation; and third, its strength at high temperatures.

An idea of its strength at high temperatures is very readily gained by referring to tests which indicate that this material has a "creep strength" in the neighborhood of 14,000 to 15,000 lb. per sq.in. at 1,000° F., as against about 3,000 lb. per sq.in. at the same temperature for mild carbon steel. These strengths are the loads which produce an elongation of 1% in 100,000 hr. So far, 18% chromium 8% nickel is the only analysis of the stainless variety that has shown itself adaptable to use in high temperature service, since the plain high chromium steels are subject to embrittlement at certain ranges.

A somewhat more recent development in this line has been a low chromium steel (approximately 4 to 6%). Being of lower price and still exhibiting increased resistance to corrosion, it is beginning to find considerable favor. In some respect this steel is a very attractive one, possessing air hardening properties and consequently a wide range in physical properties.

It has usually been found advantageous to limit the carbon content of this low chromium analysis to 0.20% or 0.25% at most, on account of its influence on the air hardening properties. By the use of an annealing process it is possible to vary the properties of 4 to 6% chromium steel with carbon 0.15% maximum, from about 60,000 to 65,000 lb. per sq.in. ultimate strength to as high as 125,000 or even 150,000 lb. per sq.in. These higher physical properties are, of course, not always retained in service, especially where such service is of a high temperature nature, as the effect of temperature over a period of time is to anneal the tube and reduce the properties to that of a soft annealed one in the neighborhood of 60,000 to 65,000 lb. per sq.in.

While complete experimental work has not as yet been completed on this steel, it may be said from preliminary data that its resistance to oxidation is better than that of mild steel, and it has a slightly higher tensile strength at elevated temperatures. Its resistance to corrosion is in the neighborhood of three to eight times that of mild carbon steel depending, of course, on the conditions of the service.

It is unnecessary to dwell much upon tubes made of the regular S.A.E. steels, as the majority of them are used after heat treatment and the properties of such material in the tubular form corresponds very closely to that of the solid section.

Pass now into the second class of tubular products, known as cold drawn tubing. We will assume that it is desired to produce from the hot finished tube as delivered to the cooling table a cold drawn tube of some smaller cross sectional area, or of closer diameter tolerances, or a better surface finish. This is accomplished by drawing the tube through a die somewhat smaller than the diameter of the original tube. The sketch on page 62 illustrates the relation of the tube in the die. A mandrel is not always used, but if one is used its size is such that the space between the die and the mandrel is less than the wall thickness of the tube to be drawn. When the tube is drawn through the die under these conditions it is apparent, of course, that the wall thickness as well as the outside diameter of the tube is reduced.

Before cold drawing the tube must be pointed on one end in order that sufficient length of reduced diameter may extend beyond the die to permit the pliers of the bench to secure sufficient grip to draw the remainder of the tube through the die and over the mandrel. Following the pointing, the tube is sent to the pickle tubs where all scale adhering to the tube is carefully removed. It is then rinsed in water to eliminate the acid. Next it is dipped in a lubricant, the purpose of which is to reduce friction and prevent metal-to-metal contact between the tube and the die on one side and the

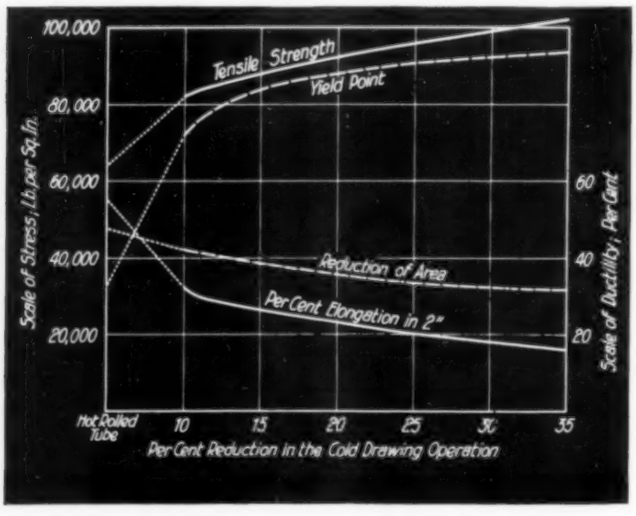
tube and the mandrel, if used, on the other.

Actual drawing of the tube is done by means of the draw bench chains and the pliers, or grips, which can be hooked into the chain after they have grasped the point of the tube. It is accomplished at a speed varying from 25 to 60 ft. per min., and the reduction in cross sectional area for one pass may vary up to 50%. Cold drawing a seamless tube section is a much more difficult operation than drawing a solid section, such as wire or shafting, owing to the fact that the internal surface introduces complications in the matter of proper cleaning, pickling and lubrication. It is also an additional friction surface when a mandrel is used.

From these remarks, which indicate in a measure the amount of work done in the process of cold drawing, it is apparent that a tube after drawing possesses considerable mechanical hardness, almost directly proportional to the reduction of area resulting from the cold draw pass. As a desired size of cold drawn tube in the smaller diameter cannot be reduced in one pass from the original 1½ or 2-in. hot rolled tube, a number of cold draw passes are often necessary. Owing to the mechanical hardness resulting from the preceding pass it is necessary to anneal the tube after each pass. In general, temperatures of 1,300 to 1,500° F. are employed for such annealing.

Two types of furnaces are used. The most common type, which is used on material relatively heavy in cross section, is of the open fire type in which the work is exposed directly to the flame. The second is a specially designed electric furnace with accurate temperature control. A further modification of such annealing is known as retort annealing, in which the tubes are placed in a cylindrical container and the ends sealed to prevent the ingress of air, thus minimizing surface oxidation. This method is especially applicable and desirable on thin wall soft annealed material.

Cold Drawing Increases Strength of 0.30% Carbon Hot-Rolled Seamless Tube and Decreases Its Ductility



Cold drawn material is for the most part termed "mechanical tubing," which term includes tubing used for all of the various applications where the tube lends itself to the construction of machinery or machine parts. The annular cross section of tubing may be desirable because of its great stiffness and strength as compared with an equivalent solid section, it may be desirable because its particular cross section lends itself to the design in question, or it may be that the use of a hollow section will reduce or eliminate the machining required to adopt a solid section to a given use. The chief market for such mechanical tubing is in the automobile industry, the reason being of course that in this industry a maximum of strength and a minimum of weight are essential. Likewise the intensive production, which is characteristic of this industry, demands raw materials which can be bought to accurate size and be fabricated with little or no machining.

It is not intended to discuss here in detail the properties of such cold drawn tubular products, but it is of interest to mention the accuracy of size and various properties of tubing which may be expected in commercial production.

Tolerances in Mechanical Tubing

Hot rolled tubing can be produced in the smaller sizes (that is, from 2 to 3 in. diameter) with a tolerance of $\frac{1}{32}$ in. on the outside diameter. This variation of course is less than the usual practice on ordinary pipe, and applies only to hot rolled *mechanical* tubes when specified in sufficient quantities to permit the adjustment of equipment to meet these limits.

Larger sizes of hot rolled mechanical tube can be produced with an outside tolerance of 3.64 to $\frac{1}{8}$ in., depending on the size and the wall. When the wall of the tube becomes relatively light in proportion to the diameter, difficulty is encountered due to ovality which results from straightening and handling.

Surface conditions of hot finished tubes are comparable with the surfaces of any similar hot finished product.

Diameters of a cold drawn tube, both inside and outside, can be controlled within very close limits. On tubes having $1\frac{1}{2}$ in. outside diameter and smaller, a maximum variation of 0.005 in. may be expected in the hard drawn, or semi-annealed condition. This variation increases with increasing diameter until at 5 in. outside diameter the maximum variation on hard drawn material would be about 0.015 in.

Surface Conditions

The surface of a cold drawn tube is much smoother than a hot finished tube and is comparable with the surface of any other cold drawn steel product. Cold drawn material lends itself particularly to those requirements where the tonnage is not great and surface appearance and extreme accuracy of size are important.

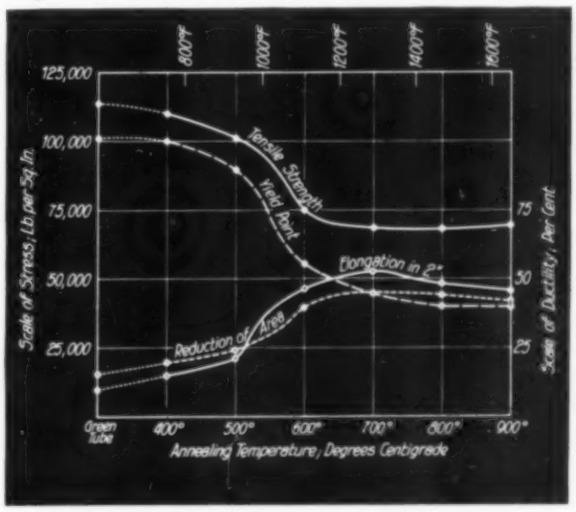
Additional possibilities are afforded in cold drawn as compared with hot rolled tube in the matter of physical properties; within limits the physical properties of a given cold drawn tube may be varied by the degree to which the mechanical hardness of cold drawing is eliminated in the final annealing operation. When the physical properties of cold drawn seamless tubing are in question, the factors which must be taken into consideration are: The analysis, the amount of cold work on the tube, and the extent to which the effects of cold work are eliminated in the final annealing operation.

One diagram on page 64 illustrates in a general way the change in the physical properties of a 0.30% carbon tube, beginning with the hot rolled condition and followed by various amounts of cold working (as measured by the percentage of reduction of the section in drawing). The properties of the metal in the hot rolled condition may be considered as normal. It will be noted that hardness, as measured by the yield point and tensile strength, increases with increasing cold work and that there is a corresponding decrease in the ductility as measured by elongation and reduction of area.

Annealing Reduces Strength

The diagram below illustrates the effect of various annealing temperatures on the physical properties of the cold drawn tube. In this particular instance a 0.30% carbon tube with 0.125-in. wall which has had about 35% reduction in cold drawing is illustrated, the curve being the product of a large number of tests. At 500° C. an appreciable relieving of the hardness has resulted, and at 600° C. a still further change is produced. From 700 to 900° C. the change in physical properties is slight compared with the change produced at lower temperatures. Recrystallization of cold worked steel begins in the neighborhood of 400° C. (750° F.) and this recrystallization is accompanied by the destruction of the effect of cold working, bringing about a gradual restoration of the original properties as found in the hot rolled tube. A series of microphotographs is shown in a Data Sheet on page 83 which definitely indicates the effect of cold work on the grain structure, and the effect of annealing on this structure.

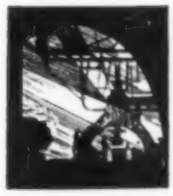
Annealing Beyond 925° F. (500° C.) Causes Recrystallization and a Marked Change In Tensile Properties. *See micros on page 83*



The Cables That Hold It All

Etching of Hudson River Bridge by O. Kühler

Editorial



Unexplained Failures a Brake on Progress

IN VIEW of his professional eminence one may accept the views of Mr. Steinman, expressed in the leading article in this issue, as representative of the progressive and successful bridge engineers in this country. He has not been timid about using high strength and even heat treated steels in his designs. Consequently, it would be well if metal men would study his remarks about the responsibility a producer must be prepared to accept in the shape of a guarantee for the safe performance of a new alloy or advanced heat treatment proposed for use in big bridges.

Steel producers will gag on this new requirement. They have been asked to conform to this and to that specification, apparently of little or no significance, but seldom if ever have they been asked to insure a structure against failure of the metal in it. Frequently sheets are bought "capable of stamping into certain shapes," but inability to perform is known as soon as the press starts working, and the steel maker's responsibility is limited to replacing or issuing credit for the unsatisfactory metal. This is sometimes bad enough, but now it appears that a firm in the metal trade which recommends a new alloy or a new joining method will be asked to put up a bond for its satisfactory performance after it gets into the structure.

Assuming that Mr. Steinman's views are the views of his profession, we are facing a stagnant future. Only in the rarest of instances will the promoter of a new material stand to gain so much by its adoption as an essential element in a big structure that he could afford to pay the insurance premium. We will have to wait until some structure *must* be built so big that standardized materials are clearly inadequate, and the builders and owners will either be forced to assume the responsibility of an innovation, or else abandon the project.

. . .

Structural engineers are more than usually shy of anything but the "old reliables" because they remember vividly the expensive failure of a highly recommended metal during the recent erection of two important suspension bridges. Fortunately, the trouble was discovered before either bridge had been completed, and consequently a major disaster and loss of life were avoided. Fortunately also, a friendly agreement was reached as to the distribution of the costs of dismantling and re-erection, but even so the financial loss was reported to be on the order of $2,000,000.

Truly an expensive experiment, not soon to be repeated!

Nevertheless, it is apparent that a stalemate will exist in the development of new and important structural materials until a clear explanation of the cause of this trouble is forthcoming. Until we know why the heat treated bridge wire first erected in the Mt. Hope Bay and Ambassador (Detroit-Windsor) bridges developed brittle breaks at the anchor shoes and under the suspender clamps, despite the fact that routine testing of each length of wire failed to indicate brittleness, all heat treated material will be suspect. The only safe course will be to try nothing new.

A quantity of the unsatisfactory wire has been at the Bureau of Standards since 1929, and eventually a report of an investigation on its properties will be made. So a lengthy and detailed discussion of the facts already known to the engineering public would be premature.

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Enough is known, however, to indicate which of the many explanations advanced of the failure are improbable, and which strike near the truth. A simple statement of these conclusions may be useful in clearing many useful materials from suspicion.

* * *

No radical changes in bridge design or erection procedure were made at Mt. Hope or Detroit except that heat treated wire was substituted for cold drawn wire. Every length of this heat treated wire passed specified tests with flying colors, and on the returns was accepted by six eminent consultants as superior to the conventional cold drawn wire. Months later, when the Mt. Hope bridge was nearing completion, fractures were observed at the anchorage shoes, and increased in number so rapidly that a collapse was narrowly averted!

The broken wires in both bridges occurred where the wire was bent into a loop about the anchorage shoe, or under the edge of suspender clamps. Fractures were localized. Therefore, they were not due to accidental variations in quality, too rare to escape the routine tests. Sporadic faults cannot be conceived as finding themselves, several hundred times, at these precise locations in the bridges.

This rules out all such suppositious causes of failure as abuse during erection, defects in the steel, variable microstructure, occasional surface imperfections, hydrogen brittleness, pickling cracks or accidental variations in any quality. The trouble was inherent in the wire as made — every inch of it.

It is improbable that this inherent unsuitability was due, as has been suggested, to the fact that the wire was basic steel made in a distant plant (rather than acid steel made under controlled conditions) or that any of the more or less unconventional practices used in its manufacture resulted in underdrawing, overheating, grain growth, or others of the variety of ills which beset wire makers. Such defects would either cause much trouble in manufacture, or should have had an unmistakable effect on the tension, bending and torsion tests.

Certainly the effects of the heat treatment did not evaporate between mill and site. Broken ends from the bridge, when tested, showed correct strength and ductility. Analysis of the stresses and examination of the fractured surfaces prove that the wires were not overstressed nor did they fail from fatigue or cyclic stresses.

* * *

Nevertheless, the presence of broken wires indicates that they carried loads too great for them to endure.

These stresses occurred where the wire had been bent to such a radius that the outer elements of the curve were stretched beyond the elastic limit, and to this unrelieved overstrain was added a slowly increasing direct stress in tension as the bridge was gradually constructed. It is probable that heat treated eutectoid steel is brittle under such creeping stresses.

We know enough about springs to know that heat treated eutectoid steel can be bent *quickly* far beyond the elastic limit, and curled into a pigtail. In valve springs they will take heavy stresses varying with great rapidity. In closely wound clock springs, they carry quiescent overstrain successfully. But overstrain of slowly increasing intensity, such as is met in the construction of a suspension bridge, was a new condition which it could not resist. A stress to which cold drawn bridge wire can adjust itself without ado caused the same steel, when heat treated, to crack square across.

Galvanizing the surface undoubtedly intensified this brittleness under creep. The zinc coating is none too ductile; the underlying zinc-iron transitional alloy is notably brittle and the "bite" of cleaning acid and alloying metal roughened the unaffected steel core. A brittle case or a rough surface are well known accelerators of brittle fractures.

But it is very probable that the real trouble lay in the inability of the heat treated metal to yield internally and relieve localized overstrain. This caused the outer circumference of the wire at sharp bends to be stretched beyond its ultimate strength at that element, and a crack to start at the surface, whereupon the microstruc-

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ture was incapable of stopping the crack once it had started.

Whether or not quenched and tempered eutectoid steel, wholly free from inclusions and segregation, with absolutely correct microstructure and a perfectly smooth surface can withstand creep stresses beyond the elastic limit, is an academic question, for such wire never will be made.

* * *

The late J. E. Howard sometimes spoke in words which did not possess that rigid precision dear to scientists. But he knew his metals. He once said, in commenting on the trustworthiness of wrought iron, that a crystalline metal does not retain its toughness at the root of a crack, while a fibrous metal does.

That tells the story of why heat treated wire is impossible for suspension bridges, while cold drawn wire is wonderful.

Flivver Planes Made of Metal Ready for Production

AT THE National Aircraft Show, several plane manufacturers indicated an intention to go after the dollars which the average man spends for transportation. A half dozen or so airplanes were exhibited which sell for less than $2000, thus being competitive with medium priced automobiles. In higher priced fields, the man who wants an airplane of his own can choose from a much larger number.

It is significant that almost all of these inexpensive planes are of metal construction in the fuselage, wing and tail structures and at least one is an all-metal ship.

Low fabrication cost is undoubtedly one great factor in the rising popularity of steel tubing and duralumin. Public preference is another. Aircraft engineers say that it is more expensive to build a wing section of wood or plywood than it is to use rolled duralumin sections when you can get into mass production, but that these costs are reversed when only a few planes are produced.

This being true, metals and metallurgy will be as important in aircraft plants tomorrow as they are in automobile plants today.

As matters stand now, wood forms the wings of three out of every four airplanes built. Steel tubing is by far the most popular of the fuselage structural materials, chrome-molybdenum tubes being in highest favor with S.A.E. 1040 in second place.

Aircraft manufacture for some time has had possibilities as a metal consuming industry, but as long as transport ships and other very expensive models are the only ones produced, the possibilities are restricted. If, however, the small, inexpensive and easily operated airplane proves safe and popular, the field will demand much metal and many metallurgists.

Ductile Steel Made Without Manganese

THOSE metal men who, 15 years ago, were in the production end of the metal business, or who were engaged in some part of the ordnance program, will remember the shortage in alloys (which almost grew into a famine as the War was prolonged) and the intensive work on new steels for new uses.

Even so common an alloy as ferromanganese was conserved to the utmost — it being something which was largely imported and something quite indispensable for sound steel. An aftermath of this situation has been the vociferous claims for protection by the infant industry exploiting our own limited manganese resources, and the continuous effort of the War department and some steel and alloy producers to develop a substitute deoxidizer and desulphurizer for steel.

Now it appears that this has been found in the form of silicon-zirconium alloy.

Zirconium, the metal, as an alloy in steel, has had a reputation sometimes good, sometimes bad. When it was rumored that the Germans were making superior guns and armor of zirconium steel, a group of metallurgists in the Ford Motor Co. laboratory, headed by C. H.

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Wills and H. T. Chandler, made some zirconium plate of exceptional ballistic properties. Several complex alloys containing zirconium had very remarkable properties, but the heats could not be duplicated with certainty.

Following this discovery at Detroit, the Bureau of Mines and the Bureau of Standards investigated complex alloys of "rare" metals, and alloy makers also studied the proper methods of manufacturing the ferros. It was determined that silicon-zirconium would readily alloy with killed steel with good recoveries, and by autumn production of special armor plate was on its way, both here and in France.

Remarkable properties were found in many of these complex steels. As an instance, one containing approximately 0.45% carbon, 1.25% silicon, 3% nickel, 0.75% manganese, and 0.25% zirconium could show in heat treated condition, 300,000 lb. per sq.in. ultimate with 7.5% elongation in 2 in. and Izod impact of 75 ft-lb. per sq.in. However, it was believed by most of the investigators that zirconium was principally valuable as a scavenger, and the superior properties of such a complex alloy were due to the other alloys it contained.

At any rate, the element lost caste with nearly everyone except the Electro Metallurgical Co. Dr. F. M. Becket, its technical director, had enough faith in the undoubted powers of zirconium as a deoxidizer to continue extensive experimentation. He made 200 to 350-lb. heats in an electric furnace and tapped the metal into duplicate or triplicate ladles. All treatment of these portions of a single heat, including heating, working, and heat treatment, would be identical except for the kind or amount of deoxidizer used — a plan with obvious advantages for studying the effect of a single variable.

By 1923 it had been found that zirconium was in effect the long-sought desulphurizer. The Bureau of Standards some years before had noted that zirconium in steel interfered with the sulphur analysis, but much large-scale work was necessary to show that such a steel forged as though it contained this fictitiously low sulphur!

Spectacular though this performance was, it appeared to be of future rather than present interest. Phosphorus had ceased to trouble steel makers since the invention of the basic process, but sulphur, once in the converter or open hearth, is there for good. It is true that the sulphur content of the available ores and scrap in this country is gradually increasing, but the danger point is still far away.

The Niagara Falls experimenters did not fail to note, in their lengthy researches, the auxiliary effect of zirconium as an excellent deoxidizer as well as a desulphurizer. This was proved by the absence of ferrite banding in zirconium treated steels, their improved cleanliness, and low gas analysis. Semi-commercial work was therefore continued, and a recent announcement by Dr. Becket before the Iron and Steel Committee of the A.I.M.E. shows that silico-zirconium has definitely been established as a substitute for ferromanganese in the manufacture of sound steel.

Electric furnace heats, so low in manganese that special raw material had to be secured to make them, were quite impossible to roll if deoxidized with ferrosilicon alone, but would roll excellently if deoxidized in the ladle with ferromanganese (as might be expected) or with no ferromanganese if as little as 0.20% of silico-zirconium was added (a new discovery). This indeed is news to the steel industry, which has known ever since Bessemer's early failures with steel from British pig irons that it is impossible to make good steel without manganese.

Fortunately, it will not be necessary for these investigators to wait for another manganese famine before they can get a return for their work. In line with the general action of zirconium as a "softener," it has been found by commercial rollings of strictly comparable heats, that steels of exceptional ductility and deep drawing ability are produced if the metal is treated with a little zirconium. A deep drawing steel deoxidized with silico-zirconium and very low in manganese (a strengthener) will have its ultimate strength and elastic limit correspondingly decreased, but in most deep drawing sheet this is a secondary consideration.

By L. W. McKeehan
Yale University

Elements of X-ray Analysis

by the powder method

ALTHOUGH von Laue and his collaborators showed as early as 1912 that X-rays could be used to investigate the structure of crystals, and although it was well known much before that date that many metals at least were predominantly crystalline, almost no progress in determining the actual atomic arrangement of metals was made until 1916. Copper, silver and gold, occurring native in obvious large crystals, and lead, deposited on sheet zinc, were investigated during this interval by Bragg's method — that is, by reflecting X-rays of known wave-length from crystalline faces. Owen and Blake showed that antimony, zinc and an alloy of copper and aluminum were crystalline, but did not succeed in deriving the structure in any of them. A few puzzling diffraction patterns were obtained from metal foils by Nishikawa in Japan, by Hupka in Germany and by Keene in England, but these had to wait for interpretation until a much later date.

In 1916, however, two investigations, one in this country by A. W. Hull and one in Switzerland by Debye and Scherrer, opened the way to a study of metals in their more usual microcrystalline condition. In the 14 years which have since elapsed, the relative merits of the titles "Hull method" or "Debye-Scherrer method" have become increasingly unimportant, and the non-controversial descriptive term, "powder method," has practically supplanted both.

In the past decade the most expert and successful applications and improvements of the powder method have been made by Prof. Arne Westgren of the University of Stockholm. His recent lectures in this country before the Franklin Institute, the Institute of Metals of the A.I.M.E. and at several universities, have shown how much can be derived from a wise use of the powder method of X-ray crystal analysis, in combination with the more familiar methods of metallurgical diagnosis. A series of articles has been prepared from these lectures, the first of which will appear in the next number of METAL PROGRESS, summarizing recent results on the structure of iron and steel. The Editor has suggested that a brief description of the powder method and a discussion of what it can tell us about crystal structures may form a suitable introduction to this series, and a supplement to the "introduction to the introduction" appearing on page 75 of the May issue.

The fundamental fact about the "reflection" of X-rays from crystals is that reflection does not occur unless there is a certain definite relation between the wave-length λ of the ray, the

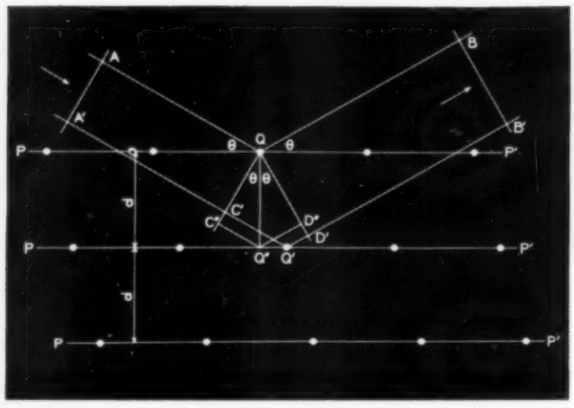


Diagram Showing Relationship Between Path of Approaching Ray and Spacing of Atoms In a Crystal to Produce a Diffraction Pattern

angle Θ at which they fall upon a crystallographic plane, and the perpendicular spacing d between adjacent *identical* planes. This relation, in the form first proposed by Bragg, is

$$n\lambda = 2d\sin\theta$$

where n is any integer. A figure is shown herewith which illustrates a simple method for deriving this relation. X-rays are approaching from the upper left and are being scattered by points arranged in crystalline array. The reflecting planes PP′ are supposed to be perpendicular to the plane of the picture. The Bragg equation results from the condition that the X-rays scattered from points in adjacent planes must agree in phase on the wave-front BB' if the incident X-rays agreed in phase on the wave-front AA'. That is, the phase difference

$$2\pi\frac{(A'Q'+Q'B')-(AQ+QB)}{\lambda}$$

must be $2\pi n$, where n is any integer. But, as can readily be seen from the figure,

$$(A'Q'+Q'B')-(AQ+QB) = C'Q'+Q'D' = C''Q''+Q''D''$$
$$= 2C''Q'' = 2d\sin\theta$$

and Bragg's equation follows at once. Theoretically a single plane can "reflect" any wavelength. It turns out, however, that the intensity reflected by a single plane is so small as to be inappreciable. Many planes must cooperate to produce a noticeable effect.

For simplicity in the above analysis, it was supposed that X-rays of only a single wavelength are allowed to fall upon a crystal. Though this extreme simplification is difficult to attain in practice, it is not hard to choose the target material in the X-ray tube and its operating voltage so that X-rays of a few wavelengths are especially conspicuous. For example, a tube with a molybdenum target operated at 30,000 volts will emit two predominant wave-lengths: 0.708 and 0.712 Ångström units respectively with a weaker radiation at 0.633 Å. (One Ångström unit is 10^{-8} centimeter.) In a copper target tube operated at 15,000 volts these wave-lengths become 1.537, 1.541 and 1.389 Å, respectively. By passing the radiation through suitable materials (as filters) the shortest of these wavelengths can be selectively absorbed, if it proves troublesome. A suitable filter for molybdenum X-rays contains zirconium. Copper X-rays are not usually filtered in this manner.

Method of Describing Crystal Planes

Assuming, then, a single known value of the wave-length λ we will place a small crystal in the X-ray beam and search for reflected rays with a photographic plate or film, or a fluorescent screen, or some other sensitive detector of this radiation.

There are, of course, in a crystal an infinite number of different crystallographic planes. Some of them will give strong reflections, and a system of notation whereby they may be adequately described is necessary.

If identical points are repeated along one of the three crystallographic axes at intervals a, along another at intervals b, and along the third at intervals c, these three lengths and the angles between the axes fix the size and shape of the unit cell. Indefinite repetition of this unit cell builds up the crystal. Any crystallographic plane (that is, a plane on which occur atom centers in a regular pattern) cuts the three axes at distances pa, qb, rc. If the plane is parallel to an axis one or two of the numbers p, q and r will be infinite.

It can also be readily shown that the reciprocals of these three numbers must be commensurate, that is to say

$$\frac{1}{q}\div\frac{1}{r} \qquad \frac{1}{r}\div\frac{1}{p} \qquad \frac{1}{p}\div\frac{1}{q}$$

must all three be integers. It is convenient to

designate the plane by three integers h, k, l, so chosen that

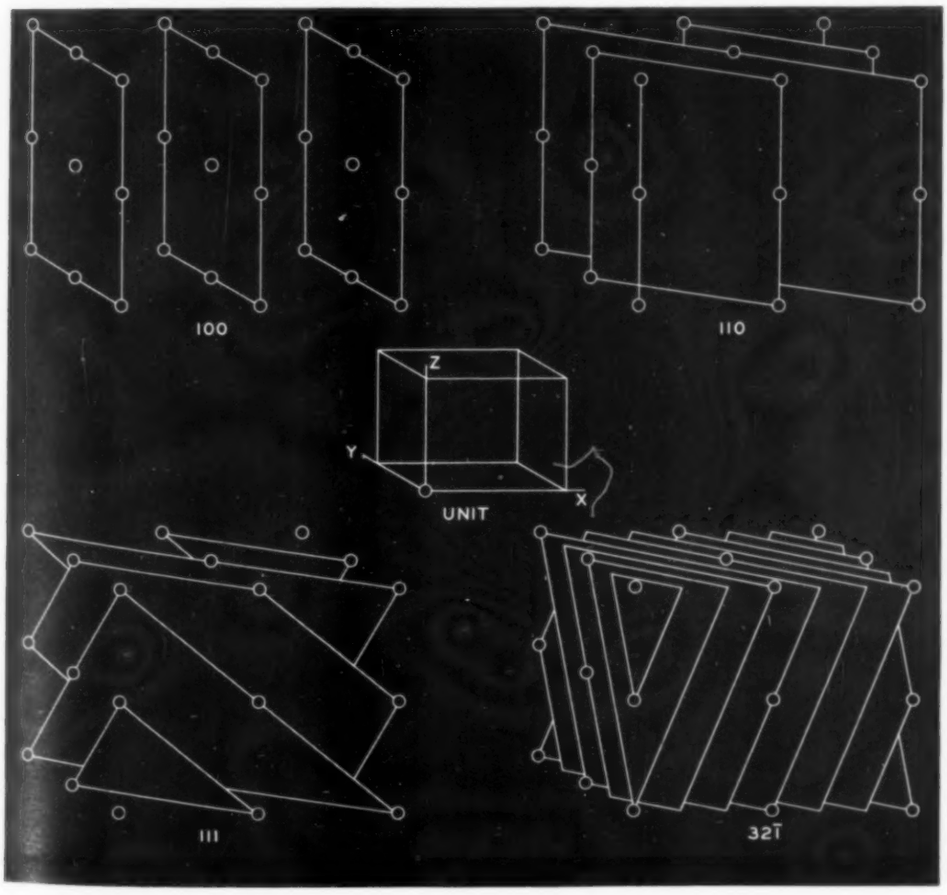
$$\frac{k}{l} = \frac{1}{q} \div \frac{1}{r} \qquad \frac{l}{h} = \frac{1}{r} \div \frac{1}{p} \qquad \frac{h}{k} = \frac{1}{p} \div \frac{1}{q}$$

The integers h, k, l, are called the "indices" of the plane considered. For all important sets of planes these indices are small numbers, not greater than 10. From the manner of derivation it is seen that all parallel planes have the same indices, and therefore a definite series of planes is fixed by the notation (hkl). If any plane is parallel to an axis, so that it cuts that axis at infinity, the index corresponding to that axis is zero.

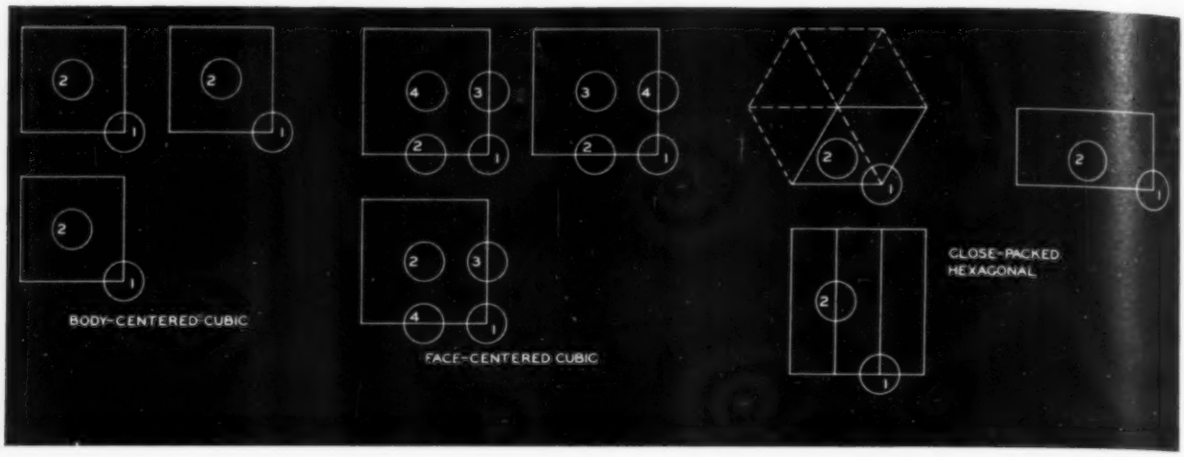
The figure at the bottom of the page shows several unit cells of a crystal and a few planes with indices as marked.

If we compute the perpendicular distances, (noted by the symbol d_{hkl}) between adjacent identical planes (hkl) we find that d_{hkl} becomes smaller as h, k and l are given higher values. This means that sin Θ, for our fixed X-ray wave-length λ, must become larger to satisfy the condition for reflection. But sin Θ cannot be greater than unity, so any reflection is impossible if d_{hkl} becomes less than $\frac{1}{2}\lambda$. For each crystal, therefore, only a limited number of Θ-values can be found for each λ-value. In the case of molybdenum X-rays reflection fails if d_{hkl} falls below 0.35 Å and at this limit the reflected rays travel back on themselves toward the X-ray tube.

A crystalline powder (or a micro-crystalline metal with no special arrangement of its crystallites) when placed in an X-ray beam having only a single wave-length, will have within it some crystals presenting each of the possible reflecting planes at the appropriate angle Θ so that X-rays will be partially reflected, and as shown from the first diagram all these reflected rays must proceed from the crystal at an angle 2Θ from the incident beam. This cone of reflected X-rays will cut a photographic plate or film in a line whose position and curvature depend upon the shape, dimensions and position of the sensitized surface. The resulting pattern



Sketch Showing the Position of 100, 110, 111, and 3,2,-1 Planes In a Crystal Block Containing 8 Unit Cubes



Plan, Elevation and Side View of the Location of Atoms in Unit Cells of Three Simple Crystal Structures

or "photogram" is the evidence from which the investigator tries to deduce the form and dimensions of the unit cell common to all the micro-crystals.

The accompanying series of drawings illustrates various experimental arrangements that have been used in getting photograms. In one the sensitive surface is a plane normal to the incident beam (which is best circular in cross-section, so made by pin-hole screens). The pattern is a set of concentric circles.

Various Experimental Arrangements

In another device the sensitive surface is a short cylinder whose axis passes through the specimen and is at right angles to the incident X-ray beam. The pattern, when the film is flattened out for inspection, is a series of lines, curved as indicated. The line for $\Theta = 45°$ is straight, both before and after flattening the sensitive film.

It is customary to use only a part of the circumference of such an axis; the part registering small deflections for general indications, the part near the entrance of the beam ($2\Theta = 180°$) for accurate measurements of d_{hkl} (or a, b, c).

The third sketch shows the arrangement used by Professor Westgren in his latest experiments. The sensitive surface is again a cylinder transverse to the incident beam, but the specimen is spread over part of the same cylindrical surface and the X-rays illuminate it through a narrow slit accurately placed on the same cylinder. Such a "focussing camera" is made of large radius if one wishes to study the smaller values of Θ. A set of three cameras covers all useful reflected rays. In either of the last described arrangements the specimen may extend some distance in the direction of the cylinder axis, and may be illuminated through slits without spoiling the sharpness of the pattern; therefore more material may be exposed to the X-rays at one time than when the beam must be limited by pin-holes.

In the fourth arrangement shown the cylindrical film has the incident X-ray beam along its axis. The pattern is extremely simple, being merely a set of parallel straight lines when the film is unrolled.

In the last the sensitive surface is a plane containing the incident beam. The specimen is spread over a ring having this beam as axis. The pattern is a row of V-shaped spots along the cylinder axis.

In all these arrangements it is necessary to provide the photographic plate or film with shields to protect it from X-rays coming elsewhere than from the specimen. The time of exposure varies from a few minutes to several days, depending upon the available source of radiation, the dimensions of the apparatus and the nature of the material studied.

Interpretation of Pattern

Suppose that by one of the several arrangements just mentioned the student has obtained

a series of values of d_{hkl}, one for each line of the pattern. His subsequent procedure depends upon what he is looking for.

If he is comparing the dimensions of the unit cells in geometrically similar crystals, he may calculate a, b, or c (in the case of cubic crystals $c = b = a$ and all are mutually perpendicular) from each value of d_{hkl}. In fixing the the best mean value he would give appropriately greater weight to lines for which d_{hkl} is measurable more precisely. He will be safe in assuming that two crystals are geometrically similar if the patterns are so much alike that every line in one is repeated in the other with the same relative intensity, and if the d-values computed by assigning the same indices to corresponding lines are proportional throughout the list.

The problem of fixing the crystal structure of an unknown material is much more difficult. The first step is to tabulate all the values for d or sin Θ. The second is to find a crystal structure which will possess just this set of values for d and sin Θ and no others.

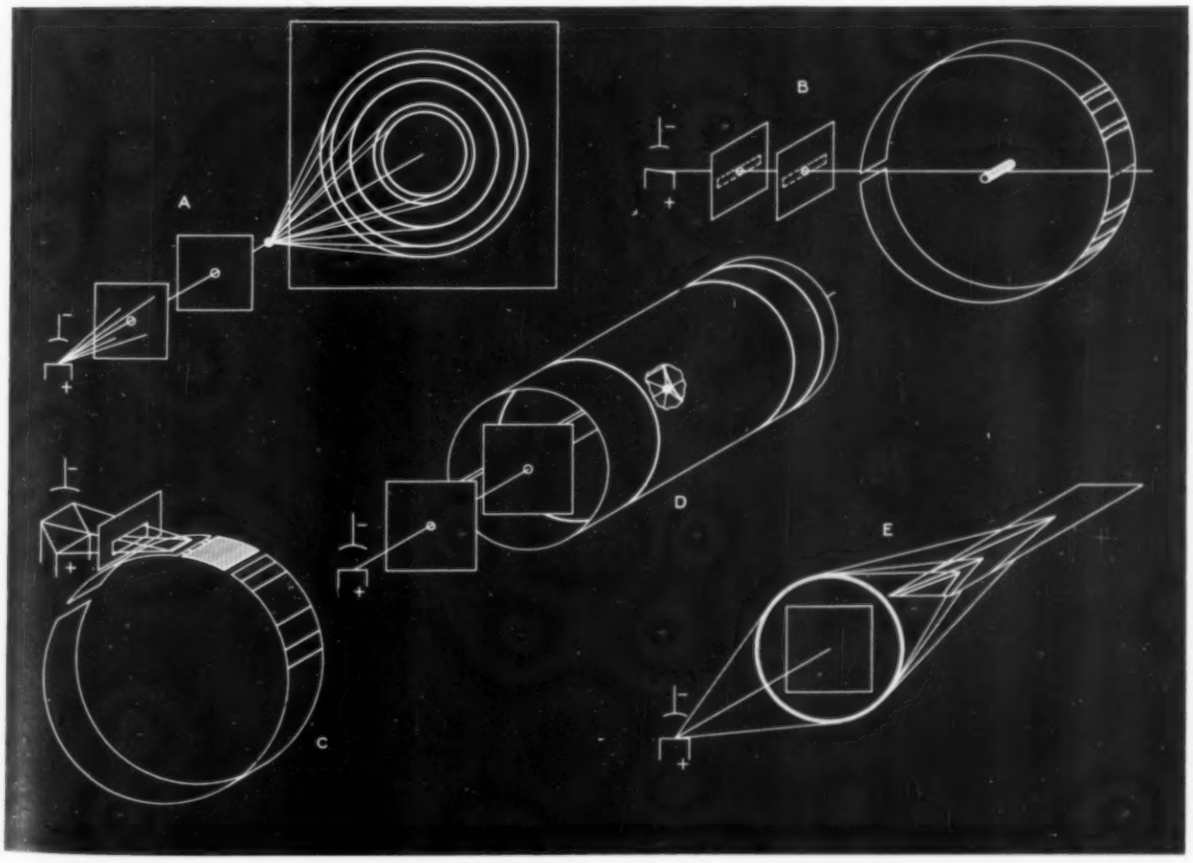
In this second step it is convenient first to assume a simple structure — that is, one in which all the X-ray scattering takes place at the corners of the unit cell. The pattern of such a simple structure will have in it more lines than the pattern of a more complicated structure with the same unit cell, but the lines of the more complicated structure must all be present in the pattern of the simpler structure.

Lines Made By Cubic Crystal

As an example, a simple cubic unit will have lines corresponding to the hkl values given in the table at the top of the next page, where for brevity only positive values of h, k, l are listed, and the lines are numbered in order of decreasing d_{hkl}.

Of these first eight lines only the second, fourth, sixth and seventh will appear if the unit

Various Arrangements of X-ray Beam, Sample to be Studied and Sensitive Film Used to Get Diffraction Patterns



Lines for a Simple Cubic Unit

Line	hkl			n
1	100	010	001	1
2	110	101	011	1
3	111			1
4	100	010	001	2
5	210 120	201 102	021 012	1
6	211	121	112	1
7	110	101	011	2
8	221 100	212 010	122 001	1 3

cube has the same atom at its center as at its corners, so as to form a so-called body-centered cube. A little practice makes it easy to recognize the patterns of the simplest structures which are: body-centered cubic, face-centered cubic, hexagonal close-packed. Sketches show units of structure of the three kinds (page 74).

More complicated arrangements cannot be easily recognized. As a, b, c (or any of the angles between them) change gradually from one value to another, the possible lines of the pattern move in a bewildering way, so that assigning the values of h, k and l to each line becomes almost impossible. In a complicated non-cubic crystal the 28 sets of indices contained in the above table may correspond to 28 different lines instead of only eight, and even this does not represent the whole increase in the complexity of the pattern, for planes with some negative indices will give still other lines and planes with some indices higher than 2 will invade the diagram.

A notion of the difficulties may be gained by considering that all we know about h, k, and l, a, b, and c and the angles (b,c), (c,a), (a,b) in the most general possible case is contained in the equation

$$\sin^2\Theta = \frac{\frac{\lambda^2}{4}\left[h^2b^2c^2\sin^2(b,c) + k^2c^2a^2\sin^2(c,a) + l^2a^2b^2\sin^2(a,b) + 2kla^2bc\{\cos(c,a)\cos(a,b) - \cos(b,c)\} + 2lhab^2c\{\cos(a,b)\cos(b,c) - \cos(c,a)\} + 2hkabc^2\{\cos(b,c)\cos(c,a) - \cos(a,b)\}\right]}{a^2b^2c^2\{1 - \cos^2(b,c) - \cos^2(c,a) - \cos^2(a,b) + 2\cos(b,c)\cos(c,a)\cos(a,b)\}}$$

We must try to find a single set of values for the atomic spacings a, b, c, and for the angles between crystallographic axes (b,c), (c,a), (a,b) so that all the observed values of diffraction angles Θ yield integral values for the indices h, k, l, and must then also find a possible arrangement of atoms within the unit of structure thus fixed so that the density or specific gravity of the crystal is correct and so that other integral values of the indices h, k, l, do *not* give reflections at missing values of Θ within the observable range.

It is safe to say that the completely general case has never been solved. Fortunately, if large enough single crystals can be found, other methods give useful data about the shape and dimensions of the unit cell, so that only the second part of the problem need be attacked.

Where no contrary evidence exists, Professor Westgren has generally made the simplifying assumption that a, b, c are at right angles, when studying complicated X-ray patterns. Sometimes the still more drastic assumption that the crystal is tetragonal ($b = a$) or that it is cubic ($c = b = a$), has been added. I think we must conclude that even a very good agreement between observed and calculated lines under these conditions is only presumptive evidence for the correctness of the proposed structure. This is particularly true where the unit cell works out to be so large that many planes of low indices do not reflect at all, and where the assignment of atoms to definite positions within the unit has not been completed. We can be perfectly certain, of course, that complicated patterns do not result from a simple structure, but the nature of its complexity must not be regarded as settled.

It would be unfair, after the pessimistic note of the last paragraph, to omit to mention that the complicated structure for alpha-manganese, assigned by Westgren and Bradley on the basis of powder photograms and its presumable cubic symmetry, seems to have been correct as shown later by supplementary methods. In this material a cube with 54 atoms in it seems well established.

It should also be emphasized that the appearance of a definite pattern with invariable positions and intensities of lines is positive proof of the appearance of a distinct phase (in the physico-chemical meaning of the term). Much of the interest in Professor Westgren's results lies in the presence of such phases in related systems, rather than in the possible intricacy of the structures tentatively proposed.

By W. A. Moore
Haynes Stellite Co.
Cleveland

Hard Facing in the Steel Industry

DURING the past few years the practice of hard facing has remarkably increased in the entire industrial field. This operation consists of welding one of several wear-resisting alloys to machine parts subjected to abrasion or to a combination of abrasion and heat. The purpose is to stabilize the wearing surface and thereby increase the life and general efficiency of the part. Inasmuch as actual job comparisons show three to six times greater life of a hard-faced part, when compared to a heat treated steel part, it is easily understood that hard surfacing is saving thousands of dollars yearly.

Stelliting, or the application of a layer of stellite to the surface of a cast iron or steel part is more of a brazing than a welding operation. The molten material from the welding rod is flowed on when the surface of the base metal is just at a "sweating" heat, and a carburizing flame containing an excess of acetylene is always used.

A survey of the applications of the process shows that the abrasion, heat, and acid-resisting properties of such alloys are of value to the makers of iron and steel from the time the ore enters the blast furnace until the finished product is cut to length. There are innumerable places during the many stages of fabrication where hard surfaced machine parts will increase production and cut maintenance costs.

To start at the beginning, consider the blast furnace department. For instance, until recently it was necessary to lower or even shut off the wind on the blast furnace before the tap hole could be plugged; nor could it be safely closed while the metal was flowing. When a new type of mud gun is used, which produces a continuous pressure and flow of clay by a screw, the operation is much facilitated. This gun consists of a right and left hand screw in a double-barreled shell. The peripheries of the screws are coated on the first two or three flights, and the nozzle has eight treated pads, $\frac{1}{2}$x$\frac{1}{8}$x7 in. long, which act as a bearing for this end of the screw and stop excessive wear of the bore. Between these pads are grooves which become filled with clay and offer sufficient resistance to prevent slippage of material past the screws. If these parts were not hard faced they would wear so

rapidly that this type of gun would be impracticable.

The auger used for drilling out the solidified mud in the tap hole may also be surfaced on the face of each flute for about ½ in., and it will then drill six times as many holes without being dressed as a hardened steel auger.

Pug mill knives for mixing the mud, treated on the edge, last about five times as long as steel, manganese steel, or chilled iron.

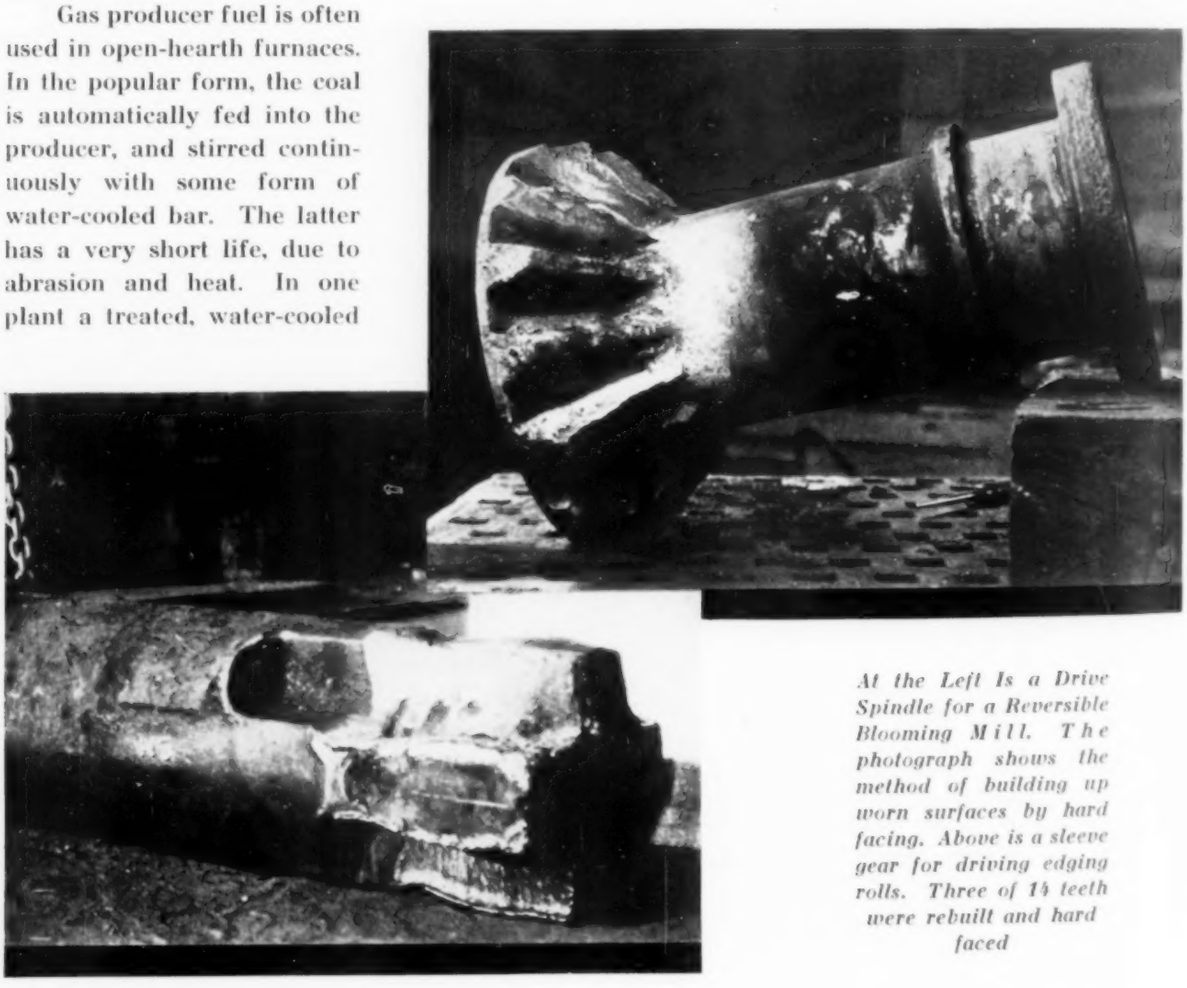
Hard facing is used extensively on coal-pulverizer hammers, coke-pusher shoes, and carbon scrapers, to mention only a few of the possible locations found in a by-product coke plant. Hard-surfaced swing-hammers usually have a life of four to six times that of hardened steel. This represents a saving not only in maintenance but also in production, for after the corners of hammers commence to wear, the output of the mill decreases. There is also a marked increase in power required to operate the mill with dull hammers.

Gas producer fuel is often used in open-hearth furnaces. In the popular form, the coal is automatically fed into the producer, and stirred continuously with some form of water-cooled bar. The latter has a very short life, due to abrasion and heat. In one plant a treated, water-cooled stirring arm has now been in continuous operation for nine months and is estimated to be about half worn, while the steel arms would last but three months. In another producer a hard-surfaced arm has run 8½ months and is showing but little wear, whereas the cast steel pokers give but three months' service on this machine.

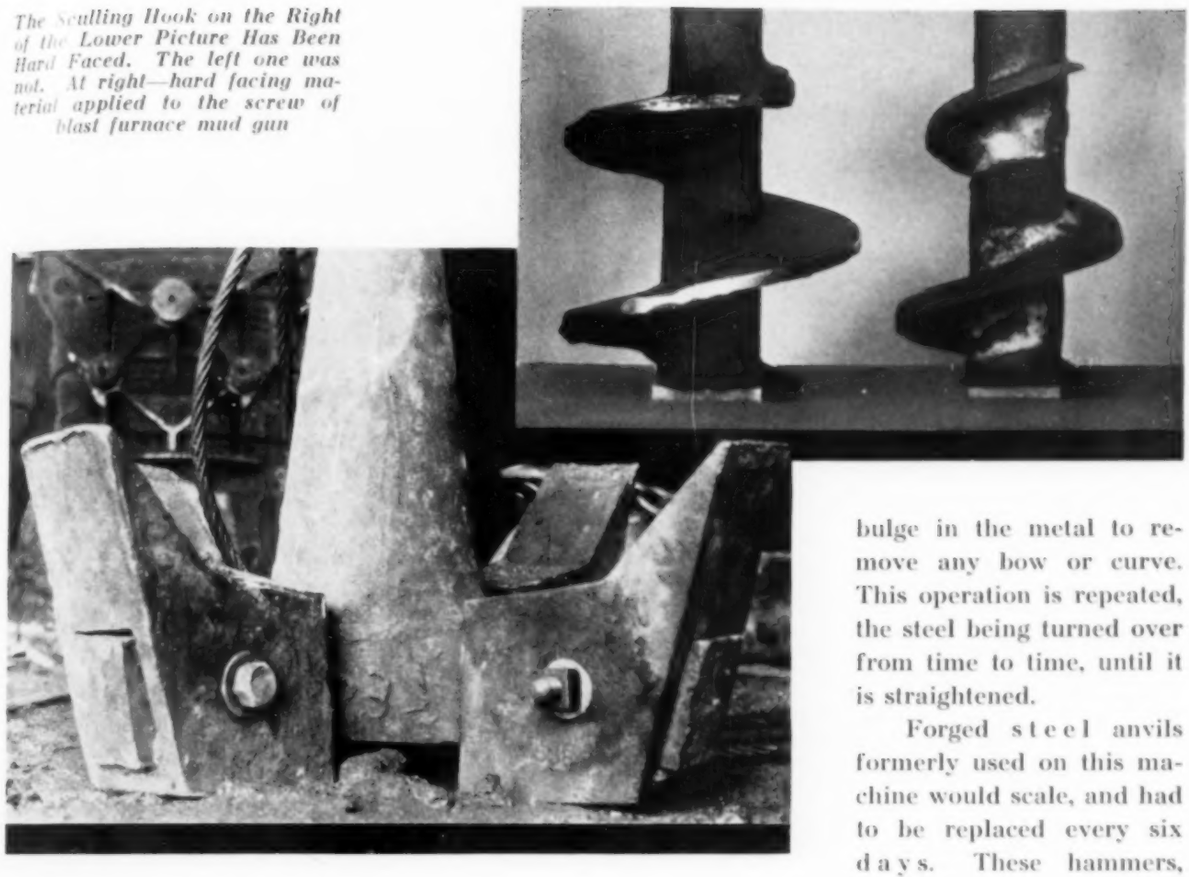
In the rolling mills great savings have been effected on the different guides.

Records from one of the largest independent steel mills show that a cast steel guide on the first finishing operation of the rail mill had to be scrapped in seven days; after the first shift it had to be dressed every three hours. A stellited guide at this point has run ten weeks without change! Not only has this been a big saving through reduction of time lost in changing guides, but the percentage of scrap and second quality rails has been considerably reduced.

Merchant mills have had equally good re-



At the Left Is a Drive Spindle for a Reversible Blooming Mill. The photograph shows the method of building up worn surfaces by hard facing. Above is a sleeve gear for driving edging rolls. Three of 14 teeth were rebuilt and hard faced



The Sculling Hook on the Right of the Lower Picture Has Been Hard Faced. The left one was not. At right—hard facing material applied to the screw of blast furnace mud gun

sults with hard-surfaced guides; some of them have reduced their inventory of repair parts to one-sixth.

Treated entry guides on the diamond passes of continuous bar and billet mills have shown a life of six to one over steel guides, and one mill using this advanced practice has reduced the inventory from 500 guides to 100.

In the rolling of skelp, the edger guides suffer severely on account of the fishtail end of the strip, which whips through the guides and scores them badly. A thin layer of abrasion-resisting material applied to the wearing surface materially increases their life.

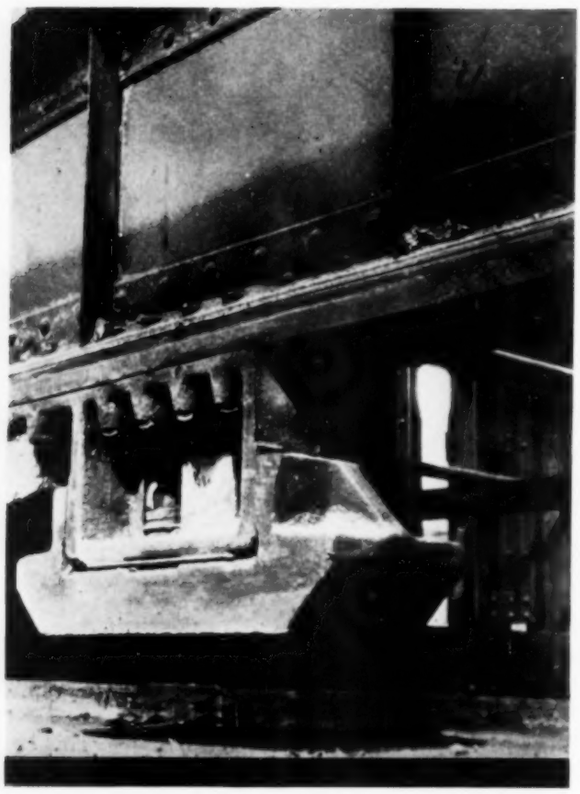
An interesting and very successful recent application is the hard surfacing of hammers in a structural mill's gag press. It straightens the steel on the run-out table. As the shape leaves the rolls, it passes between cramps — three anvils on each side, all electrically controlled by an operator. With the steel in motion, the leading and trailing pairs of anvils push forward and support the steel between them and one of the center hammers pushes against the bulge in the metal to remove any bow or curve. This operation is repeated, the steel being turned over from time to time, until it is straightened.

Forged steel anvils formerly used on this machine would scale, and had to be replaced every six days. These hammers, which are 8 in. wide by 30 in. high, are now being hard faced with wear-resisting alloy $\frac{5}{16}$ in. thick and 1 in. wide, $\frac{3}{4}$ in. being left between pads. Such hammers will run for 90 days, making a ratio of fifteen to one over steel — a remarkable saving both in upkeep and continuous production.

Bearings are Hard Faced

One labor-saving machine in sheet and tin plate mills, called the Poole feeder, separates the sheets and feeds them one at a time through the tinning or galvanizing pots. Bearings on this machine, particularly on the top rolls, are subjected to severe pressure and suffer from lack of lubrication due to heat from the molten metal or attack of acid from the flux. Extensive repairs each week-end have been accepted as almost inevitable. Hard facing the bearings makes them last for the life of the rolls and this method is now standard practice in many tin plate mills.

Other hard surfacing applications on the Poole feeder are the throw-out mechanism,



A Coke Pusher Shoe, Hard Surfaced on the Bottom to Reduce Wear By Abrasion

cams, and cam pads on the doubler roll, and on adjusting screws and cams. These parts were formerly made either of chilled iron or hardened steel, but even these were not very satisfactory; because of the severe abrasion, they wore very rapidly and had to be replaced frequently.

Cam Life Greatly Lengthened

Wire mill mechanics have found hard surfacing a solution of some of their knotty problems. There are, for instance, a great many cams on nail machines. The steel pinch cams will run for only about three months before they have to be replaced. An application of hard facing alloy $\frac{1}{16}$ in. thick for two-thirds of the periphery will increase the life to 18 months or more. Pad and adjusting screws of cut-off levers and double draft block rings are also coated with consequent economy in the costs of maintenance.

Punches and dies for hot work also form a logical field for stelliting. One of the large manufacturers of steel car wheels is now blanking the center hole of forged steel wheels at a temperature of 2,000° F. The hub of this wheel is 8 in. thick and the hole is $4\frac{3}{4}$ in. diameter. A cast iron punch formerly used had a life of from three to ten holes; a carbon steel punch with $\frac{5}{16}$ in. of its cutting edge covered with hard alloy will punch from 100 to 160 holes.

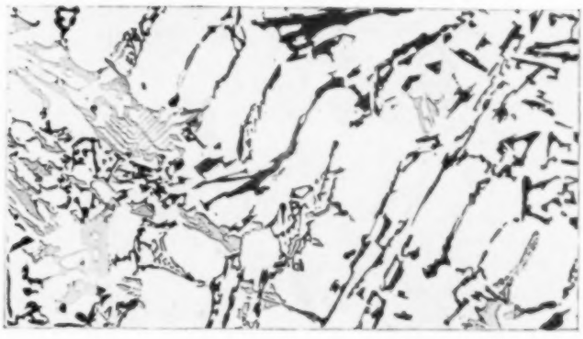
Machining Costs Cut 40%

Another advantage of the hard-surfaced punch is that it leaves a cleaner hole. Only one machining operation is required to finish the wheel, whereas it was customary to take two cuts. The cost of machining has been reduced about 40%.

Such a list of applications of hard-faced surfaces in the steel industry by no means exhausts the possibilities. The list is merely indicative of the extensive opportunities which are open to an intelligent maintenance department. Furthermore, it should be suggestive to manufacturers — machinery which is destined to work in severe locations should obviously be armored in advance.

Knock-Out Blocks for a Drop Hammer to Which a Hard Surface Has Been Applied

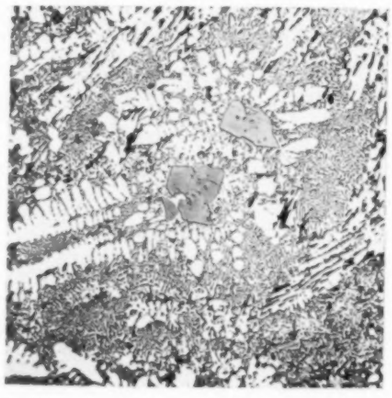
Commercial Aluminum Piston Alloys



Coarse structure of slowly cooled alloy, not obtained commercially but showing constituents

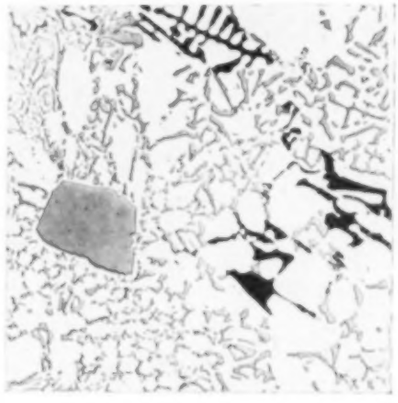
White background is aluminum-rich solid solution; black particles, Mg_2Si; dark gray, silicon; medium gray, nickel-aluminum; and light gray contain copper, nickel, and aluminum. Iron is distributed between medium and light gray constituents. Sample is unetched and photographed at 100 diameters magnification.

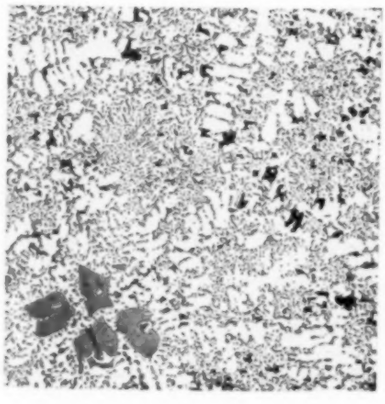
Magnified 100 Times



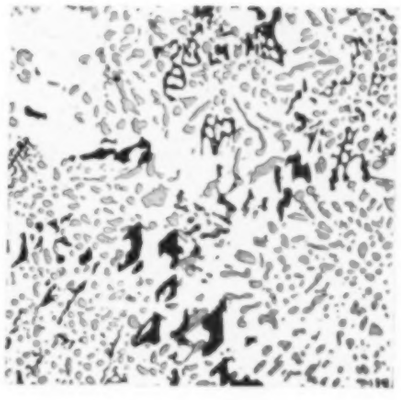
As-cast structure of chill cast ½-in. sections showing aluminum-silicon eutectic. Primary silicon, gray; nickel-aluminum, copper-nickel-aluminum and Mg_2Si, black. Etched with aqueous solution of 0.5% HF.

Magnified 500 Times



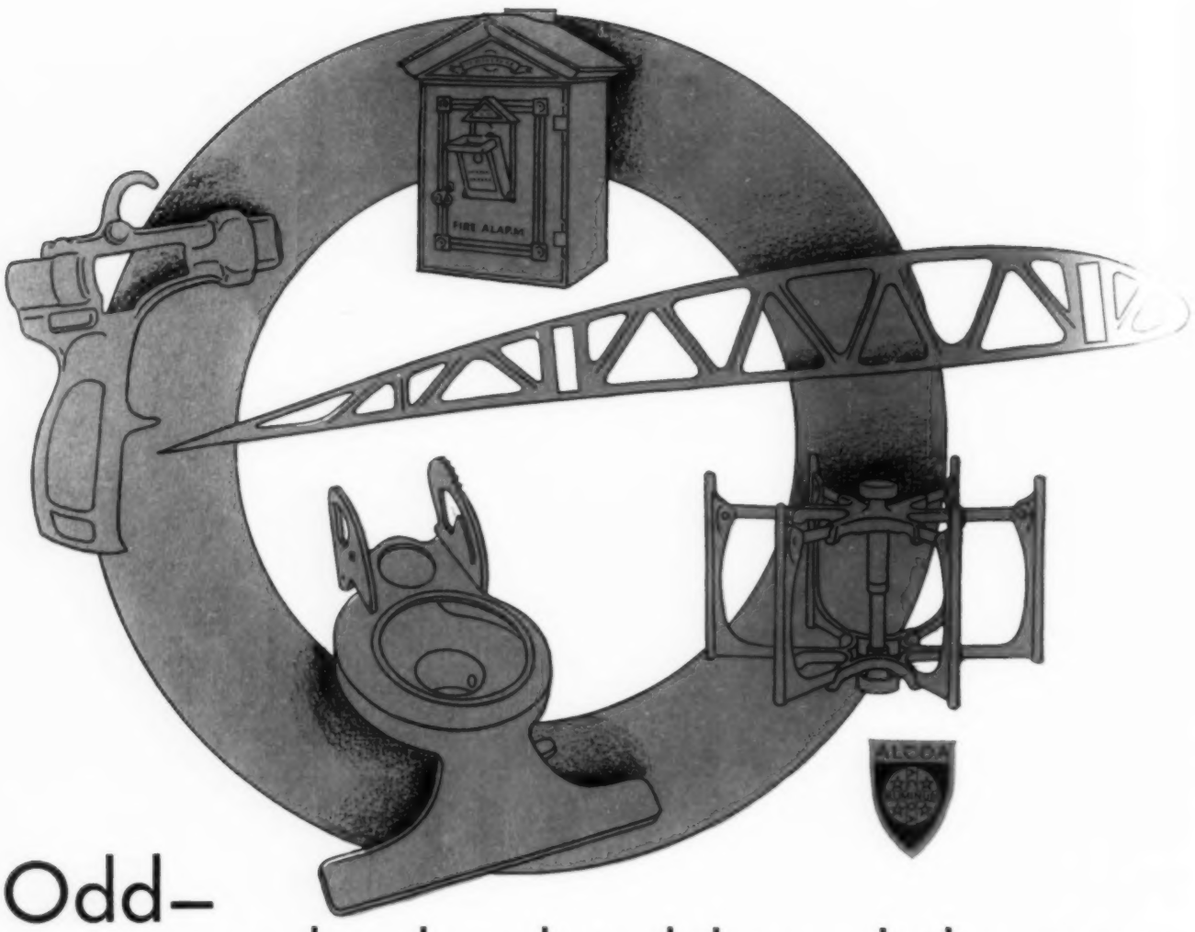


Chill cast ½-in. section quenched from high temperature solution heat treatment. Some of the Mg_2Si and silicon has been dissolved in the aluminum and the excess constituents have been spheroidized. Etched with aqueous solution 0.5% HF.



Aluminum Company of America's No. 132 Alloy. Typical composition: Copper 0.8%, iron 0.7%, magnesium 1.0%, nickel 2.3%, silicon 14.0%

Photomicrographs by Aluminum Research Laboratories



Odd—

yet closely related through the strong alloys of Alcoa Aluminum

A suction sweeper chasing dirt—a bobbin whirling silk—an aerofoil, a spray-gun, a fire alarm box—all are related. Children of a thousand brains—products of a thousand factories—are "sisters under their skins" because they are made of the strong alloys of Alcoa Aluminum. When you design that next gadget, consider the many advantages of Alcoa Aluminum and its strong alloys.

The strong alloys of Alcoa Aluminum unite great strength—up to 55,000 lbs. per sq. in. minimum—with extreme lightness. They have superior heat and electrical conductivity. The parts that are made of them resist corrosion. They finish readily to an attractive surface that retains its good looks. With all their other advantages, the cost of the strong alloys of Alcoa Aluminum is low—comparable to other metals lacking such specific advantages.

The strong alloys of Alcoa Aluminum are now being used in thousands of ways, and are effecting economies whether they are used as forgings, stampings, castings, screw machine products or otherwise. Standard metal working equipment can be used in their fabrication.

The experience of our research and product engineers, are yours to check against your own production. Write to us, let us discuss with you the profit opportunities in the strong alloys of Alcoa Aluminum. ALUMINUM COMPANY *of* AMERICA; 2501 Oliver Building, PITTSBURGH, PENNSYLVANIA.

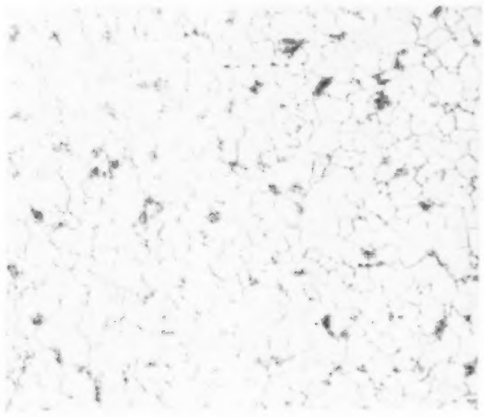
ALCOA ALUMINUM

Microstructure of Cold-Drawn Seamless Tube

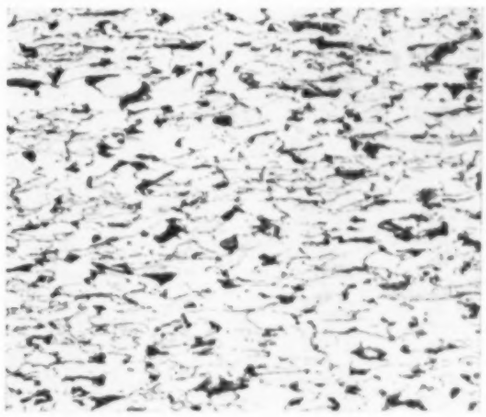
Soft Steel, 0.10 to 0.20% Carbon

Magnifications 100 dia.

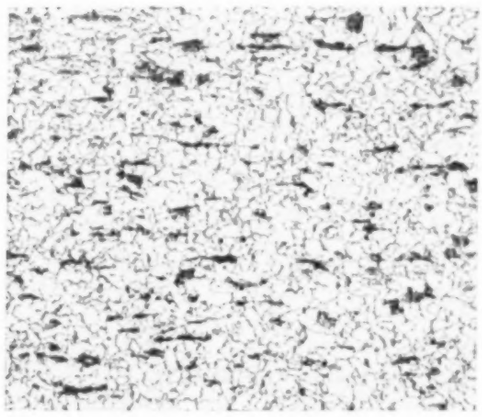
Etched in 5% HNO_3



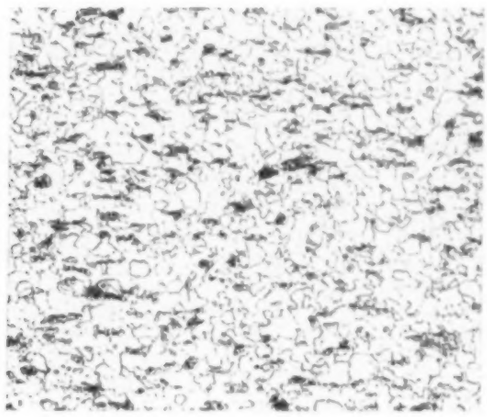
Reduction of 10% by cold drawing has little if any effect on orientation of the grains.



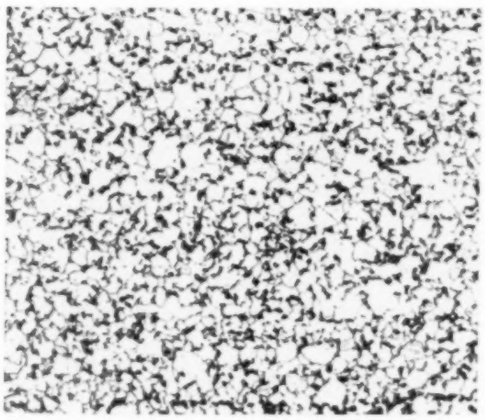
Reduction of 50% by cold drawing gives pronounced fibrous appearance to ferrite.



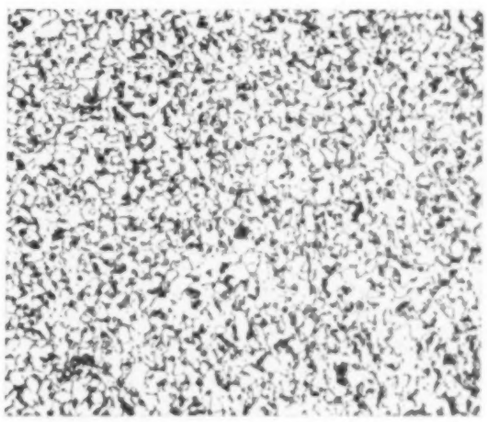
Reduced 50%, Annealed at 600° C.



Reduced 50%, Annealed at 700° C.



Reduced 50%, Annealed at 800° C.



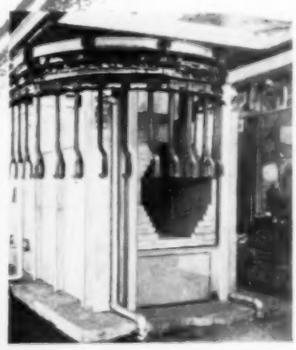
Reduced 50%, Annealed at 900° C.

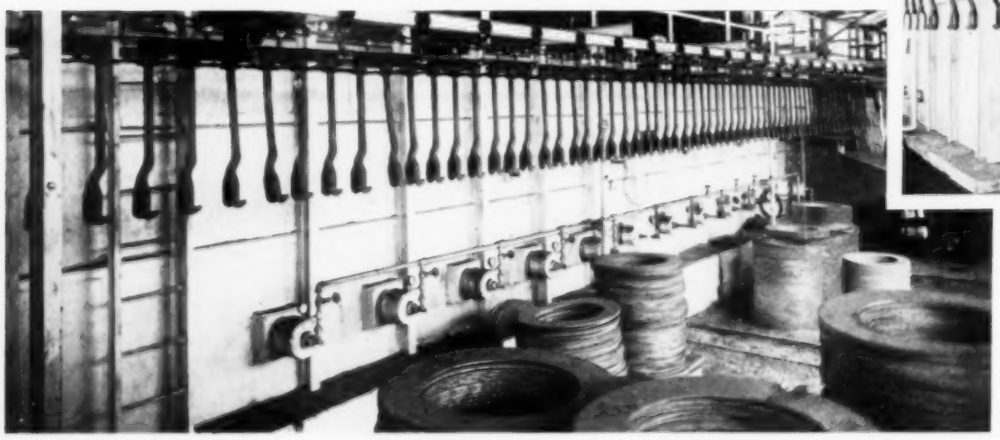
Stages in Recrystallization of Ferrite and Cementite

Photomicrographs by National Tube Co. Laboratory

LEADING MANUFACTURER SOLVES
PIPE COUPLING PROBLEM WITH SC CONTINUOUS FURNACES

LONG distance transmission of natural gas . . . through pipe lines thousands of miles in length . . . necessitated couplings safely withstanding pressures up to 800 lbs. To meet these exacting requirements the S. R. Dresser Manufacturing Company, Bradford, Pa., built a large addition to their plant. Two Surface Combustion continuous gas-fired furnaces, with complete overhead conveyor mechanisms, were installed. The forming furnace operates at 1750° F., delivering blanks to the presses at 1600° F. Partially finished flanges are re-heated in an SC reheating furnace and returned to the press for punching of bolt holes, which completes the operation. Production capacity is 18,000 net lbs. of work per hour.





ABOVE—Entrance End of Furnace showing empty Conveyor entering.

LEFT—Close-up of furnaces showing arrangement of burners, conveyor, etc.

OPERATED BY HENRY L. DOHERTY & COMPANY

Surface Combustion

SURFACE COMBUSTION CORPORATION
TOLEDO, OHIO.

SALES AND ENGINEERING SERVICE
IN PRINCIPAL CITIES

Correspondence and Foreign Letters

AS HAS already been pointed out in former letters, the light metals industry, including the production of pure metals and the manufacture and treatment of their alloys, has developed very rapidly in Italy during the last few years. This is easily explained by the fact that this development has taken place more slowly than the development of the industries using the light metals, so that the new concerns manufacturing light alloys are now finding a big domestic market for the sale of their products. In addition, they do not find many difficulties in meeting foreign competition, as they have at their disposal practically unlimited quantities of excellent raw materials and cheap labor and electric power.

A Peculiar Behavior of Light Alloys in Fatigue

I have already reported a few facts concerning the new Italian plants for the production of aluminum. Before telling about the recent applications of the light alloys, I want to point to the fact that the rapid development of these new applications has enormously increased the interest in light metal research. It may be interesting to learn of at least one example of the results obtained in this field of research within the last few months.

One of the researches may be cited whose results seem to open the way to new fields of investigation, where important practical applications are possible. These studies were begun recently by Prof. Gustavo Colonnetti and his coworkers in the laboratory for testing materials at the Engineering School, Turin. Their object is the study of the elastic hysteresis of the aluminum alloys.

These investigations have disclosed that many aluminum alloys, already widely used, have cycles of elastic hysteresis with some peculiar characteristics which are quite different from those of other alloys and vary widely for relatively small variations of their composition and of the cold work or heat treatments which have been given them.

For brevity's sake, the results of the numerous experiments carried on by Colonnetti cannot be reported in detail. I will confine myself to summarizing those referring to three aluminum alloys, widely known and largely used in industry. The first of these alloys (known here as "lautal") contains approximately 94% aluminum, 4% copper, and 2% silicon. The second ("avional") contains 94.5% aluminum, 4% copper, 0.5% silicon, 0.5% manganese, and 0.5% magnesium. The composition of the third ("anticorodal") is 97.8% aluminum, 1% silicon, 0.6% manganese, and 0.6% magnesium. These three alloys have been studied under various and exactly determined conditions — hot rolled, cold drawn and after different heat treatments.

The major difference observed is that the elastic behavior of lautal, the first alloy, is very

similar to the well-known high percentage copper alloys or high nickel steels. On the other hand, the behavior of the others is *entirely different* in nature.

For these last alloys the normal stress-strain curve shows a rather extended concavity turned toward the vertical axis. This indicates that the modulus of elasticity increases with increasing loads. Then the stress-strain curve deflects to the right, following the expected behavior, and the modulus begins to decrease.

This characteristic has an important effect on the action of them under fatigue. The initial value of the modulus (which, in fatigue testing, is found every time the direction of loading is abruptly reversed) is not a maximum, but is relatively low. On lowering the load further, the modulus increases, at first very slowly, then more rapidly, until it reaches the maximum value, when the hysteresis loop is closed.

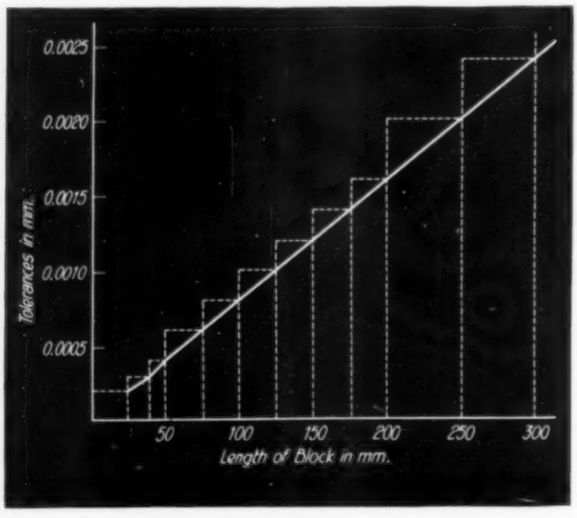
Stress-strain curves traced during decreasing loads show a concavity toward the horizontal axis, and (provided the yield point has not been surpassed) lies entirely above the curve of increasing deformations.

Even if we leave aside any attempt at a thermodynamic interpretation of these peculiar facts, which appear inconsistent with fundamental physical laws, it is evident that the results of these accurate experiments of Colonnetti are of very practical importance in the study of the technical applications of aluminum alloys of high strength.

FEDERICO GIOLITTI

Turin, Italy.

Relation of Tolerances to Length of Gage Blocks; Johansson Method



Tolerances and Hardness of Precision Gage Blocks

AN ARTICLE on gage blocks by Charles M. Pond which appeared in the March issue of METAL PROGRESS was very interesting and suggests the following remarks.

He mentions that each block is accurate to the millionth. In European practice we have two systems of tolerances, namely, Johansson's and another sometimes used in France.

Johansson assures the trade that his blocks have such tolerances that they are interchangeable, no matter how many blocks are used for a certain length — even if only one is used. This statement is confirmed by the accompanying chart; along the horizontal axis are plotted the lengths of the different blocks, and the vertical are the corresponding tolerances.

On the other hand, a French firm, Précision Mécanique, makes blocks to a uniform tolerance of 0.0002 mm. Of course, such a system does not permit interchangeability.

It seems to me that Johansson's system of tolerances is superior to the system of the single tolerance used independently of the length of the block. From Mr. Pond's statement that each block is accurate to the millionth, however, arises the supposition that the Pratt & Whitney system of tolerances does not permit interchangeability.

A note on the hardness of blocks may also be of interest. European practice gives the following results:

Johansson blocks vary from 63 to 66.5 on the Rockwell C scale. Blocks of Zeiss make

measure 61 to 64. Blocks made by Précision Mécanique are nitrided. Blocks made in Poland average 61.5 to 67 on the Rockwell C scale.

J. Zubko

Brwinow, Poland.

* * *

As we at Pratt & Whitney see it, Mr. Zubko does not view the question of tolerances from the same angle as we do in this country. Our practice is exactly the same as Johansson's in that we have a greater tolerance for the greater lengths. Judging from his letter, one of the European tool makers is trying to hold all lengths within eight millionths, and it is quite easy to see that they will run into difficulties when making 3-in., 4-in., and even longer blocks.

If all blocks are maintained within the required tolerance, there is no question but that interchangeability will be assured. The prime difficulty with blocks is in maintaining them to size and still using them. In shop use they are often allowed to wear until they are undersize a great deal more than the permissible tolerance for new blocks. Again they are improperly seasoned by the manufacturer and grow to a marked extent after they reach the user.

It is quite interesting to note that the Rockwell hardness readings taken from various European blocks indicate clearly that those manufacturers are keeping on the soft side to prevent such growth.

Charles M. Pond

Hartford, Conn.

Limitations of Tests for Iron Castings

PHYSICAL testing of cast iron is a problem of long standing. Studies and experiments have been made for several years in every country to define and to specify acceptable iron castings.

Undoubtedly acceptance tests of materials have considerable influence on industrial development; at times they play a part in stimulating progress, often they utterly paralyze manufacture. It is a well-known fact that the tests imposed by artillery officers and naval constructors have influenced metallurgical development by directing attention to the special steels (especially nickel-chromium steels), which later inspired the motor-car industry and later yet, the aircraft manufacturers. Contrariwise, some examples of defective tests might be mentioned as having hampered an industry for years — a prominent one in my mind concerns the hydraulic limes of the Parisian region.

It is consequently essential to choose wisely the appropriate tests which will show precisely and efficiently the real properties of materials so as to develop their quality and uses as well as to increase their security.

What makes the problem, as it relates to pig iron, more intricate is that iron's physical properties depend not only on the chemical analysis of the raw materials but also on its thermal history, its pouring temperature, casting method, and cooling speed.

The cooling speed is influenced by a considerable number of things which are called "foundry factors." They are so numerous and so complex that they cannot be defined nor measured; one of these, the shape of the piece, varies to infinity.

Physical properties depend on the shape and dimensions of the pieces, and for the same piece they are variable from one point to another, so that:

1. To compare the physical properties of two cast iron pieces, these must be identical and cast under the same molding and gating conditions, in all the details that this statement implies.

2. To define the physical properties of a piece, the piece itself must be tested.

Physical properties cannot be derived from the results obtained from a few test pieces separately cast, for it is impossible to evaluate certain important factors such as shape, gating, and pouring. It is impossible also, by means of a single dimension, such as the diameter of a test bar, to express the three dimensions of space or the curve radius of the surface. Some pieces of the same thickness will have entirely different

properties if they have the shape of a cube, or of a round or square bar, or of a plate.

Two clearly distinct problems must therefore be considered in any comprehensive and rigorous solution:

1. To classify cast iron while it is in a liquid state. To do this, furnace men must cooperate by reporting on the analyses, raw materials, mixture, and to realize the influence of melting methods and of temperatures, and to control and make uniform the production of liquid pig iron.

2. To classify the physical properties of castings. This problem chiefly concerns the purchaser, and the tests must be made on the piece in question or on an identical one cast under identical conditions.

These two distinct problems were acknowledged by the International Foundry Congress, held in Paris in 1923, as a starting point for future researches and tests. Committees were then created to work on them in every country, and also an International Committee designed to coordinate the efforts of the individual committees.

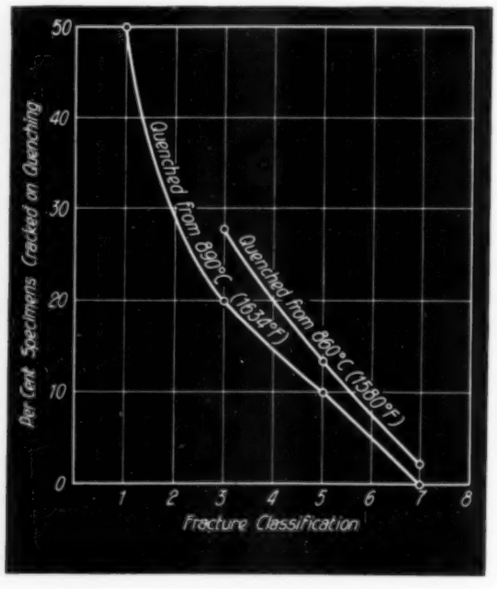
We must note the great improvements made in the physical properties of gray iron castings with regard to increasing their durability and physical similarity. To continue this good beginning and to take advantage of these improvements, further tests must be made until it becomes possible to estimate later behavior in service.

It is to be hoped that the International Foundry Congress to be held at Milan next September will publish researches undertaken in every country, record improvements, and produce an interchange of ideas which will improve and unify the methods of testing cast iron.

ALBERT PORTEVIN

Paris, France.

Classification of Tool Steel By Fracture Will Reduce Liability of Quenching Cracks



Classifying Hardened Tool Steel Fractures

DR. RAGNAR ARPI of Hagfors Jernverk recently received from the hands of the Crown Prince a prize awarded by the Royal Swedish Academy of Sciences. It was given to him in appreciation of his work in developing a method for testing the quality of tool steel by examining the fracture of quenched specimens.

Manufacture of high quality steel being of a relatively greater importance to the Swedish steel industry than to that of most other countries, it is no wonder that a good deal of work has been done lately on methods of testing tool steel. While it is, of course, recognized that the only reliable method of ascertaining the quality of a tool steel is to test tools made from the steel in question under carefully standardized working conditions, such a procedure must necessarily require a considerable time. A rapid and reliable method of testing is therefore greatly needed, and the method must permit grading the material.

Dr. Arpi has prepared a scale of fracture-classes, zero designating a very coarse-grained fracture and ten the finest fracture obtainable. The test is made on a number of notched bars which are quenched in water from different

temperatures, such as 750, 770, 800, 830, 860, and 890° C. The bars are then fractured, and classified by comparison with standards. Similar methods have been used both in Germany and America (see Mr. Shepherd's article in February METAL PROGRESS), but the thorough testing of this method carried out by Arpi and other Swedish investigators brought to light new facts of considerable interest.

Although the method is both rapid and clear, it cannot always be said to be reliable. While steels with a wide quenching range (fine-grained fracture at widely differing quenching temperatures) also show good results when practically tested as tools, a narrow quenching range may not necessarily mean inferior quality. As shown by the diagram on page 88, there is, however, a very definite relation between the fineness of the fracture and the liability of the steel to crack on quenching.

Of more interest is an apparently distinct relation between the quenching range and the refining process — especially deoxidation. It might therefore be possible to develop this test into a method for continuous control of some of the primary factors governing steel making, which would facilitate the production of a uniform quality of steel.

EINAR ÖHMAN

Stockholm, Sweden.

Meeting of Japanese Iron & Steel Institute

THE SPRING MEETING of the Japanese Iron & Steel Institute was held April 4, in Tokio. Nineteen papers were read, important among them being one by T. Sato on the equilibrium diagram of the system iron cementite, iron sulphide; another by I. Iitaka on "Chrumin," a new light alloy which is not corroded by seawater; one by S. Umezu on the reduction of titanium oxide; a paper by K. Iwasé on the catalytic reduction of iron sands and iron oxides; one by K. Ueno on the production of vanadium steel from Kuji sponge iron; and one under the joint authorship of K. Honda, G. Takamaé, T. Watanabé, on the ballistics of light armor.

Chrumin, according to Dr. I. Iitaka, the inventor of the alloy, can be used as a cast or forged alloy. In the cast state it has the following constants: Tensile strength, 27,600 lb. per sq.in.; yield point, 15,400 lb. per sq.in.; elongation 13.8%; Izod impact 6.5 ft.-lb.; Brinell hardness 69; and density 2.71.

In the form of a drawn wire, the alloy has a tensile strength of 58,300 lb. per sq.in. In a salt water of 5% concentration, it stands four years without producing any precipitation.

K. HONDA

Sendai, Japan.

Taking Temperatures of Crucible Steel at Vikmanshyttan, Sweden. Photo by Erik Walldow

Casting Aluminum Pistons

in permanent molds

By G. D. Welty
Aluminum Co. of America
Cleveland

THE REAL HISTORY of the aluminum alloy piston may be said to begin in 1915 with the introduction of the permanent mold process for fabricating piston castings. Previous to this a few pistons had been cast in sand, but these were soft, porous and generally unsatisfactory. Many problems were of course involved in making the first permanent mold pistons, and it was not until much money and energy were expended that the problems were commercially solved.

S.A.E. specification No. 34 is well adapted to the process. This material, containing about 10% of copper, 1.2% iron, 0.25% magnesium and balance aluminum, was the result of many searching experiments endeavoring to discover an alloy which would satisfy the exacting requirements of service, and which would also be adaptable to the new method of casting. The soundness of the final decision is indicated by the fact that during the past 15 years about 100,000,000 piston castings have been made in permanent molds with little or no change in alloy composition.

A permanent mold for the ordinary piston casting consists essentially of two halves. It carries the impression of the external contour of the casting, and parts along a plane perpendicular to a line joining the centers of the wrist-pin bosses. These two mold-halves, in opening and closing, slide on a cast iron base which also serves to form the piston head.

The internal contour of the casting is formed by a collapsible steel core which is assembled into the cavity after the two mold-halves have been locked in position. The core may consist of three, five, seven, or even nine separate pieces depending on the complexity of the particular design.

A gate is cut, partly in each mold-half, leading first into a goose-neck trap for collecting dross, and then to a smooth channel, curving downward into the bottom of the mold cavity, so that the metal enters without splash.

A feeder or shrink cavity is also provided in the mold-halves adjacent to the piston cavity and connected with it. This shrink cavity is of relatively greater section than the piston itself, so that the metal in it will remain molten and feed into the latter as crystallization shrinkage takes place. This helps to produce a sound, perfectly filled casting. An additional shrink cavity and riser are usually provided on the side of the mold opposite the gate.

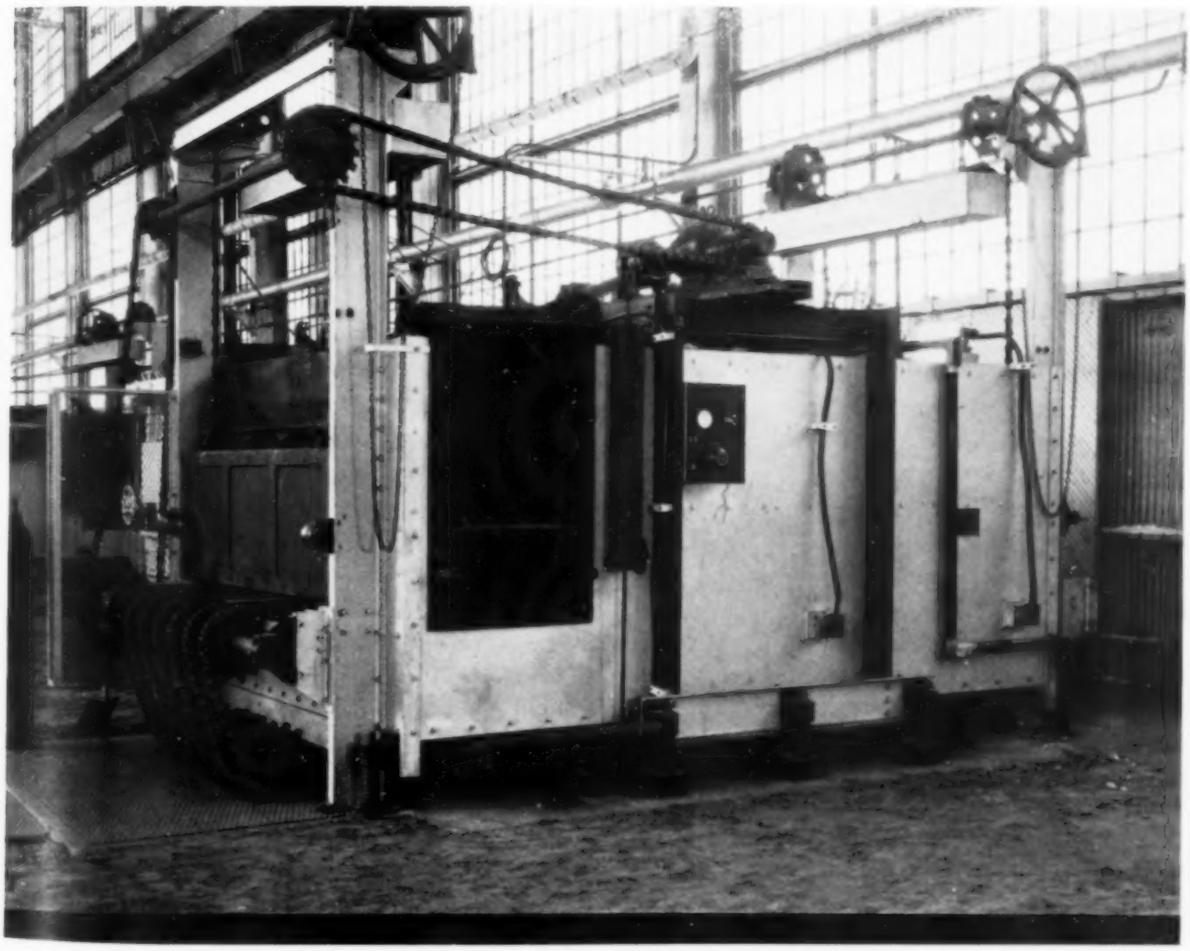
No pressure other than gravity is applied to the metal at any time during the casting process.

The wrist-pin bosses are cast hollow with just enough finish to clean up satisfactorily in machining. This is a two-fold advantage in that it saves metal and results in fine grained structure in the wrist-pin bearing as a result of the chilling effect of the core pins. This chilling effect may be further accentuated by dipping the core pins into cold water just before assembly into the mold-halves, or by constructing them of some material, such as copper, which has an extremely high thermal conductivity.

Very large pistons for Diesel engines, such as the one illustrated in this article and which are required in relatively small numbers, are frequently cast in a "semi-permanent" mold. This process involves the use of metal mold-halves with a sand core, which greatly reduces the cost of the equipment and at the same time provides, in a considerable degree, the benefits to be derived from a chilled casting. Pistons weighing several hundred pounds are frequently cast by this method.

The successful construction and operation of such permanent mold equipment depends upon a great amount of experience gained over a considerable period of time. Special materials are used in mold and core to insure satisfactory life and freedom from warpage and erosion. Venting must be properly provided (to allow exit for air and gases) or the cavity will not fill. Operating temperatures must be maintained within relatively narrow limits. If the mold is too cold, as when starting up, the castings will not fill out; if it is too hot, the shrink cavities will not function properly. In some instances it is necessary to secure the proper temperature

Electric Furnace With Automatic Control, to Operate at About 900° F. Pistons are given the "solution" heat treatment in this furnace



balance by applying gas flames to certain parts of the mold. Many details of construction of the molds, as well as certain basic features of the casting process itself, are covered by United States patents.

Three main advantages may fairly be claimed for the permanent mold piston as opposed to the sand cast product:

1. Better physical properties, such as a very notable freedom from casting defects, greater hardness, greater toughness, improved qualities, and improved machining properties.

2. Lower cost. A large number of these castings may be produced with great dimensional uniformity and with minimum finish.

3. Better response to heat treatment. Pistons made by this process are susceptible to improvement by heat treatment to a much greater degree than are pistons cast in sand.

Some remarks on the possibilities of heat treatment will be especially interesting to readers of METAL PROGRESS. Improvement of aluminum alloy pistons by heat treatment depends primarily upon the precipitation from solid solution of hard particles of the compound $CuAl_2$ in submicroscopic size. The process is sometimes carried out in two steps — a solution treatment followed by a precipitation treatment. Sometimes the hardening is done by a single precipitation treatment. Both of these possibilities have been discussed at length in a paper entitled, "The Hardening of Metals by Dispersed Constituents Precipitated from Solid Solutions," by R. S. Archer read before the A.S.S.T. at Chicago, September, 1926.

In the process we are now describing the solution treatment at about 900° F. followed by a quench may be omitted, because the permanent mold casting process is *in itself* a very effective solution treatment. The rapid solidification and subsequent cooling of the piston casting in a metal mold results in a supersaturated solution of $CuAl_2$ in aluminum. Some of this hardening compound may be precipitated by a subsequent treatment at between 300 and 400° F. Brinell hardness numbers ranging from 70 to 150 may be produced at will by this method with great consistency and uniformity. This increase in hardness is accompanied by increases in tensile strength and elastic limit, resulting in increased resistance to wear and distortion, all of which is reflected in better service and longer life. A Brinell hardness number of 110 to 125 has been found to offer a most desirable combination of properties. The problems of other motor builders seem to be met by harder pistons, in the range from 125 to 150 Brinell, and many are furnished to this specification.

Battery of "Aging" Tanks Used for the "Precipitation" Heat Treatment on Aluminum Alloy Pistons. Superheated steam gives a sufficiently high temperature

Equipment for carrying out the solution treatment includes electric furnaces with accurate pyrometer control, and a quenching arrangement. Precipitation or "aging" treatment may be carried out either in an electric furnace or in a tank heated with steam, the latter being preferable for ease of temperature control and for economy.

A recent notable development, known as "Lo-Ex" alloy, contains about 13% of silicon with small quantities of copper, magnesium, and nickel (balance aluminum), and is already in extensive use in the aircraft field. Prominent manufacturers of automobiles, trucks, motorcycles, and marine motors have also adopted it. A series of photomicrographs of this alloy (also known as No. 132) is shown on page 81 in the editorial insert.

Its advantages over S.A.E. Specification No. 34 are three in number:

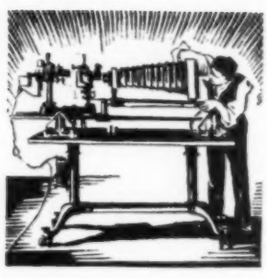
1. It possesses a lower coefficient of thermal expansion.
2. It is approximately 10% lighter.
3. It has superior qualities as a material for the construction of bearings.

Diesel Engine Piston, Cast of Aluminum Alloy By Semi-Permanent Mold Process, Compared With Permanent Mold Pistons Made for the Automotive Industry

Low Expansion an Advantage

Its lower coefficient of expansion permits the closer fitting of pistons without danger of sticking or scoring. This feature is of particular importance in the aircraft field where clearances in the past have been large and must, if practicable, be reduced. Of course the lower specific gravity of this alloy is also much in its favor since any reduction in the reciprocating weight of a rapidly moving element is always of prime importance in obtaining smoothness of operation. The chief drawbacks to the more extensive use of this alloy have been foundry problems, which are now pretty well solved, and the fact that it requires cemented tungsten carbide tools for machining. These tools, however, are rapidly coming into common use, so that difficult machinability will soon cease to be a problem to motor manufacturers.

A Metallurgical Detective Story



JOHNNY JONES dashed forth one Christmas morning to show his friends a new bicycle, and stumbled over a five-pound box of candy left at the front door — evidently by mistake, for it was addressed to Naomi Hall, a person unknown to Johnny or his mother.

For a week the gift was put first here and then there; a constant temptation to Johnny, whose repeated pleadings to open the package were denied by the mother. Then the mystery of Naomi Hall was cleared by a neighborhood friend, who knew that some newcomers down the road were called Hall. Two children, a big sister and a mother. So on New Year's morning Johnny, going to town on an errand, delivered the package to its rightful owner.

He had not left the premises when a terrific explosion almost demolished the cottage. Neighbors, running to investigate, were horrified to find the mangled remains of the two children and the big sister, and the unconscious form of the mother.

Enter the sheriff and his deputies. From them and the injured mother the coroner's jury learned that the Halls had moved to Seat Pleasant, Md., from a farm some miles away, where they had borne a good reputation and had no known enemies. The daughter, who was shortly to become a mother, had secretly married a young farmer named Herman Brady, a rather lackadaisical youth from her old home.

Herman, when questioned as to his movements on Christmas morn, when the box was left at Johnny's house, had no difficulty in proving that an older brother Leroy had driven over from Washington and the two of them had gone duck hunting in some marshes in the southern part of the state, leaving home before dawn, and thus were 80 miles from the Jones home when the infernal machine was found.

A detective assigned to the case had visited the Hall cottage, and was lucky enough to find that he had been forestalled. Two boys were poking about in the wreckage, looking for souvenirs. The explosion had torn a great hole in the floor, and grubbing around in the earth below they had found some metal fragments. The detective, being an intelligent detective, recog-

nized that these might have some value as evidence and commandeered them — but they did not mean anything to the coroner's jury. "Death by violence; murderer unknown" was the verdict, and the case seemed destined for that growing list of unsolved mysteries.

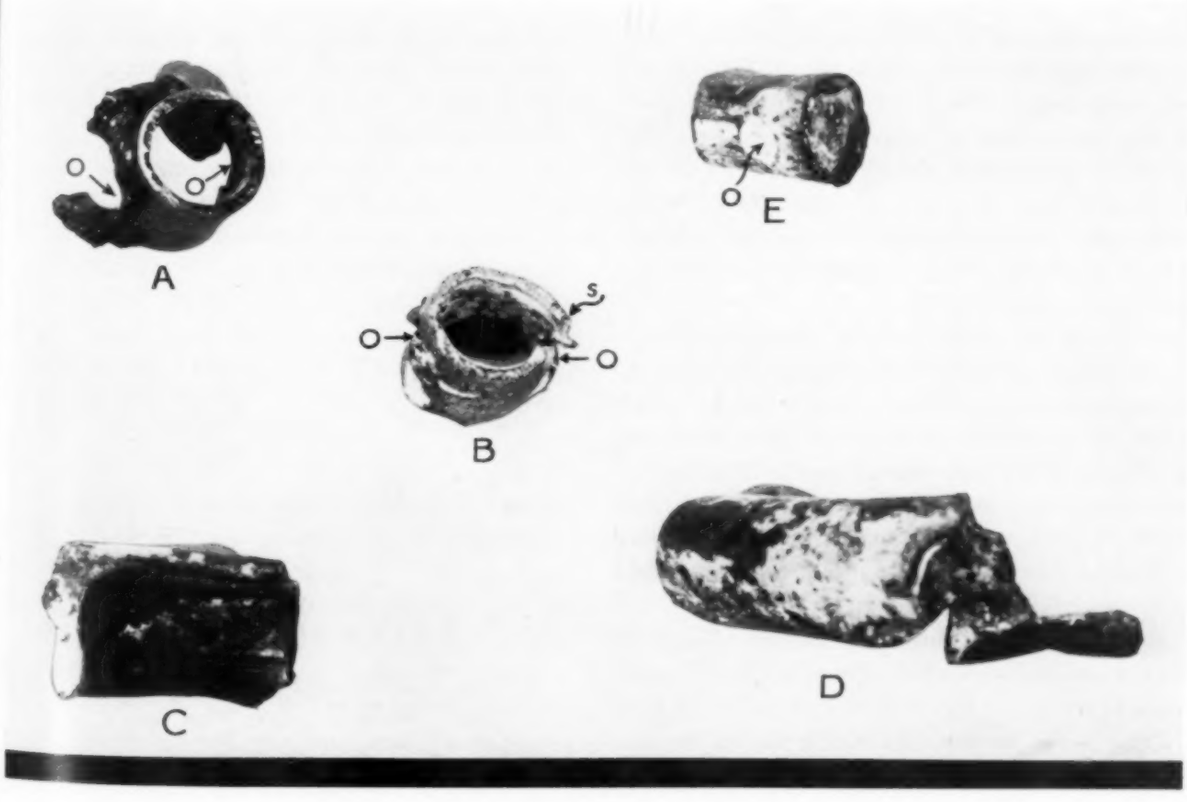
However, the District Attorney, shocked by this particularly atrocious crime, was unwilling to drop the case. All the material evidence had been destroyed by the explosion, with perhaps the exception of the metal pieces found by the boys and another recovered by a later systematic search. Could these give any information? In this dilemma he turned for advice to Prof. R. W. Wood, head of the physics department of Johns Hopkins University, who besides being a physicist, is a ballistic expert of sorts.

The fragments not readily identified as debris from household furnishings were six: Three short pieces of thin-walled tubing, about ⅜ in. outside diameter (pieces A, B and C in the attached photograph) a second and longer piece of tubing D, crushed flat, a stubby piece of ¼-in. rod E, with a copper disc welded on one end, and another piece of ¼-in. rod (not shown), one end of which was turned to a smaller diameter.

On slitting the crushed tubing (Piece D) and opening it out flat, two tiny stirrups of metal fell out, which looked like chain links broken apart at the weld. Perhaps a light chain had been inside the tube. But, as shown on page 96, the interior wall of the crushed tube had certain corrugations pressed into it which could hardly have been made by chain links. These markings were something like a crude screw thread; where the tube was flattened the marks were very plain, but at the sharp bends they did not exist. They were probably the cast of the wire article originally inside the tube, rather than an interior thread, which of course would have run clear around the inner wall.

Professor Wood was puzzling over how spiral markings could be made by a chain, until he studied the character of the breaks in the wire. It then became clearly evident that if the

Five of the Six Fragments of the Infernal Machine. A, B, C and D are tubing; E is a rod. O represents drilled holes, S a longitudinal slit. Magnified two diameters



Corrugations Inside Tube D, and the Wire Fragments Which Dropped Out. Magnified 5½ diameters

fessor Wood pried this off some tiny particles of white metal adhered to the edges. Testing these beads with a magnet indicated that they were iron — evidently torn from the plug when the copper was removed.

The small piece of tubing *C* also had small fragments of thin copper sheet adhering to it. This piece also had evidences that the wall had been slotted or perforated by a tool.

The ferrite microcrystals in this and all the other suspected pieces of low-carbon steel were strongly marked with Neumann bands — a fact established by the metallurgical department of the Bureau of Standards — ordinarily accepted as evidence that metal possessing them has been subjected to violent shock.

Professor Wood's conclusion was that this short rod was a striking anvil and the copper disc was the flattened out casing of a percussion cap, partially fused to the low carbon steel at the instant of explosion by heat and pressure. The surrounding tube had been blown apart by the resulting explosion and fragments of copper adhered to it as well.

Inquiry among fire arms dealers in Baltimore then brought out the information that

little stirrups were reformed into a circular chain link the two ends would not fit together — one break was square, the other was at an angle with the axis of the wire. However, one end of one stirrup did fit into one end of the other, and in such a way that the two pieces formed a complete turn of a spiral. How simple! What the tube contained was not a chain but a spring. The stirrups were also of hard steel, too hard for chain, just right for springs. Furthermore, when Professor Wood secured a piece of light tubing and a steel spring from a hardware store, slipped one inside of the other, and then hit the tubing a lusty blow with a sledge, the tube acquired markings similar to the one under investigation. Not so deep, yet having undoubtedly the same characteristics.

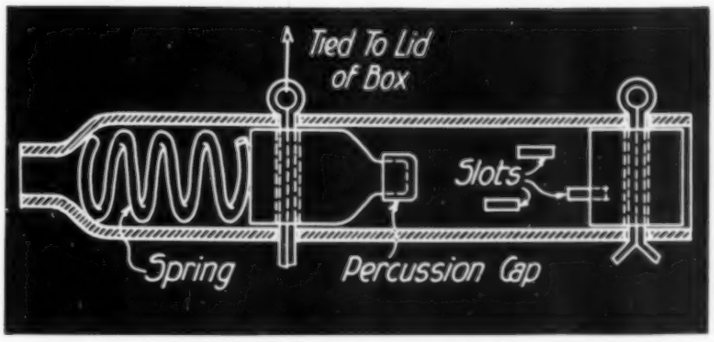
The stubby piece of ¼-in. rod, *E*, and fragment *A* of the tube were particularly interesting. These are shown to larger scale in the third view. *A* was the very end of the tube, for it had been cut off with a hack saw. One fitted inside the other, and both had a small hole drilled through, which fitted in such a way that the rod *E* might have served to plug the tube end, pinned in place by a cotter.

One end of the rod *E* was depressed slightly in the center and flared a little around the circumference. To this end was attached a thin copper disc, perforated roughly in the center, as is clearly shown at the right. When Pro-

Close-up of Pieces A and E Showing Perforated Disc of Thin Copper on End of Rod E. Magnified 3½ diameters

there are three makes of caps easily purchased; of these, two have brass casings, copper-coated. The third, made by Remington Arms Co., has a sheath of pure copper of the thickness found in the suspected piece. Furthermore, it was found that a Remington cap makes a snug fit over the turned-down nose of the other piece of ¼-in. rod which had been previously found at the ill-fated Hall cottage.

Reconstruction of a hypothetical firing mechanism was then easy. The small tube had the ¼-in. round fixed at one end. The other end carried the hammer, with the percussion cap on its nose, backed by some compressed springs, and held in place by a pin. When the lid of the candy box was opened, a string pulled this pin, released the hammer to fly down the tube, and explode the cap and dynamite.

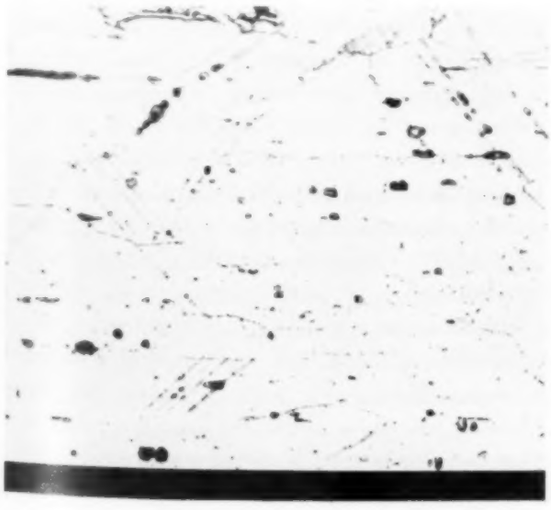


Reconstruction of Infernal Machine from Fragments

The Murderer's Inspiration

Having sketched this device, Professor Wood showed it to the District Attorney. "That's just the way a rabbit gun works," said he. "What's a rabbit gun?" asked Wood. "An automatic gun for killing small game," said the other. Unfortunately this clue was misleading. A rabbit gun owned by Herman Brady's younger brother, had a firing mechanism equivalent to the reconstructed bomb, but it was intact and made of different sized tubing and springs. The culprit, therefore, might have gained his ideas from dismounting a rabbit gun, but he evidently used metals which he obtained from some other convenient source.

Neumann Bands In Metal Fragments. Magnified 500 diameters



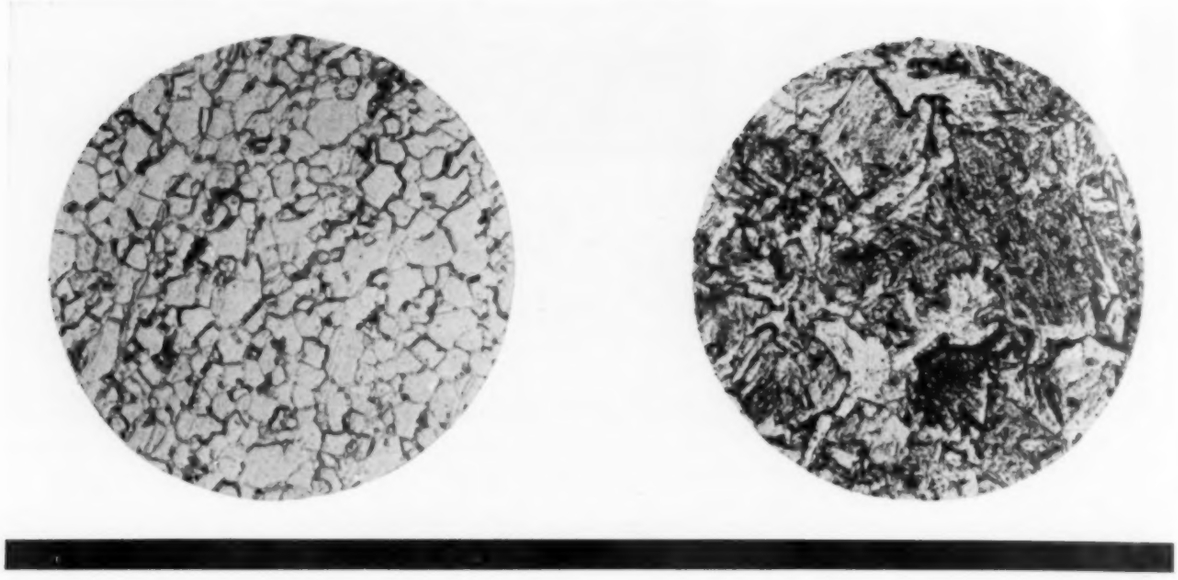
Just where did he get them? What manufacturing industry, what repair shop, had these materials readily available? Some place where precisely this tube, springs, cotters and rod were to be found, there the murderer was lurking. The bomber evidently had free access to a drill press, because of the holes found in hammer and tube, but he probably had no lathe, for the anvil was crudely fashioned — possibly also in the drill press by chucking the round bar in place of a drill and reducing the spinning end with a file.

So far so good, but nearly every machine shop or garage has these simple materials and tools available! But no one seemed to be able to identify the tubing. No hardware jobber in Baltimore carried the stuff in stock; in fact, its dimension did not correspond to the standards for any class of goods known to them. Likewise all fragments of the tubing had three fine parallel scratches on the outside along the welded seam — a fortunate imperfection in the forming or trimming dies. These lines (clearly shown in the first view) proved that the suspected pieces were mates, and would identify any stock from which the bomb had been made.

The Microscope's Contribution

Microscopic examination of the tube showed that it was made of low carbon strip, with lon-

Microstructure of Tube Wall and Weld Indicated That It Was Made By Resistance Welding. Etched with alcoholic picric acid; magnified 250 diameters



gitudinal seam butt welded. It was slightly upset along the joint on the inside wall. Furthermore, the grain structure at the joint suggested a resistance weld. Any flash or thickening on the outside of the longitudinal seam had been rolled or trimmed off — probably the latter, for the scratches seemed to be made by a poorly adjusted cutter.

Tubing made from thin strip by resistance welding corresponds to the product manufactured under patents owned by Steel & Tubes, Cleveland.

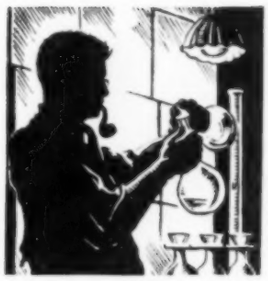
The Tubing Is Traced

A sample was sawed from one of the fragments and sent to that company; it promptly brought the information that, while it was of its manufacture, it was not a standard product, but a bastard size and thickness made to order of General Motors and shipped to the Chevrolet plant. Chevrolet engineers in turn identified it as the raw material for a torque rod inserted in the steering post connecting the throttle to the carburetor.

This information, of course, narrowed the search. The spring corresponded exactly in wire gage and outside diameter to a short helical spring used on Chevrolet door latches. The ¼-in. round steel rod could be had anywhere — could be cut from a ¼-in. machine bolt, for instance. Wherever a piece of scored tubing and the springs could be found, there was the place to look for the murderer.

Thirty pieces of such tubing were found in central Chevrolet headquarters in Baltimore, but none of the lengths were scored by the peculiar markings. Nevertheless, the trail led directly to the Chevrolet service station in Washington — a shop which possesses a drill press, but no lathe. In this shop was found a piece of tubing, scored lengthwise by three lines, exactly the same as the bomb fragments. In this shop was employed Leroy Brady, brother-in-law of the murdered girl, an ingenious mechanic whose pastime was making remote control electrical devices. The younger brother owned a rabbit gun, which Leroy was "repairing" a few weeks before Christmas at the garage (although ballistic experts testified that the gun had never been discharged). Lastly, Herman Brady, the young husband, owned a muzzle loader, and a box of Remington percussion caps was found in the Brady home.

Alloys of Iron and Oxygen



By C. H. Herty, Jr.,
U. S. Bureau of Mines
Pittsburgh

THROUGHOUT this article the term "iron-oxygen alloys" is used to mean iron oxide (probably FeO) dissolved in iron. It is realized that all implications of this terminology may not be correct but it does express fairly satisfactorily the intended meaning.

The element oxygen is found alloyed in iron in varying amounts in all steels. Oxygen exists in steel either as iron oxide (FeO) in solid solution, as small amounts of manganese oxide (MnO) in solid solution, or in the non-metallic matter distributed throughout the steel.

The oxygen in this non-metallic matter generally consists of manganese oxide, silica, and alumina, either as such or in various combinations. If special deoxidizers are used, there will also generally be small amounts of resultant oxides present in the steel. Oxygen in these forms, however, is not to be considered as alloyed with the iron, as it is present as non-metallic inclusions.

In all steel making processes iron oxide is dissolved in the steel at some stage of the melting. In the basic electric furnace the amount present is at a minimum, whereas in the open hearth furnace and in the bessemer converter there may be, dissolved in the liquid steel, up to 0.50 to 0.60% FeO. Upon deoxidation the amount of iron oxide is reduced, depending entirely upon the type and amount of deoxidizers used.

From a commercial standpoint, alloys of iron and oxygen are of little importance. This statement refers to any beneficial results from the oxygen content of the finished steel. However, it is necessary to have a high oxygen content in the process of steel manufacture in order to reduce the carbon to a low concentration. Oxygen is, therefore, of considerable importance in the manufacture of very low carbon steels where the desired factor is low carbon rather than high oxygen. In this respect, oxygen may be considered a necessary evil.

Iron oxide lowers the melting point of iron approximately 10° C. when 0.94% FeO, (0.21 per cent oxygen) is present (1). (The numbers in parentheses refer to the literature citations at the end.) The solubility of iron oxide in iron is 0.94% at the melting point (2). With increasing temperature above the melting point, the solubility increases and at 1600° C. the solubility is 1.37%. In commercial steels the iron oxide in liquid steel is less than the amounts stated, so that the finished steel contains variable amounts, ranging from traces up to 0.27% FeO. The solid solubility of iron oxide in iron is about 0.22% (1), which is an estimate based on microscopic evidence, so must be considered merely an approximation. In a recent investigation Krings (3) found the solid solubility of oxygen in iron to be 0.11% (equivalent to 0.494% FeO) at 715° C.

A constitutional diagram of the iron-oxygen system, as determined by Mathewson, Spire and

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Release

Milligan(8) from various sets of data, has been printed as a data sheet, April METAL PROGRESS.

Alloys of iron and oxygen forge well at high temperatures. Austen(4) found that the alloys were difficult to work in the neighborhood of 900° C. but this was not observed by other investigators. Cain(5) has found that oxygen in the presence of considerable amounts of sulphur causes steel to be red short, but if the sulphur is very low the steel is not red short up to fairly high oxygen contents. Tritton and Hanson(1) and Bureau of Mines investigators(2) found no difficulty in hot working iron-oxygen alloys, and in both these cases the sulphur content was very low — below 0.010%. Austen gives no sulphur values for his alloys, and it is possible that the red shortness might have been due to a combination of oxygen and sulphur.

Iron-oxygen alloys, according to Austen(4) were fairly corrosion-resistant in air, being better than mild steel, but they were more easily corroded in water and in weak acid than mild steel or wrought iron. Austen found that the 900° C. critical point was lowered slightly, but this was not checked by Tritton and Hanson's work, who found no change in critical points.

The iron-oxygen alloys are very brittle under impact testing(1 and 2). The hardness increases slightly with increasing oxygen contents(2 and 4), and the ductility decreases with increasing oxygen content(1). Very high oxygen contents make iron cold short(1). The electrical resistivity of iron is increased considerably by oxygen(2), and apparently the increase in resistivity is due to the FeO in solid solution, as the resistivity is unchanged over a considerable range of oxygen contents above this solid solubility limit.

Apparently the ultimate strength of iron is not affected by the oxygen content, but the elastic limit is lower than reported values for pure iron(2).

According to Yensen(6), oxygen has a very great effect on the magnetic properties of iron. No definite results are given, and work on this phase of the physical properties of iron-oxygen alloys is continuing at the Westinghouse research laboratory, East Pittsburgh. Yensen states that high silicon steels for magnetic purposes probably owe their excellent properties to the extremely low oxygen content rather than to the high silicon content.

Iron-oxygen alloys when carburized show structures in which the cementite is always massive and very little pearlite is observed under the conditions of the McQuaid-Ehn test(7).

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3. W. Krings and J. Kempkins, Zeitschrift Anorganische Chemie, 1929, Vol. 183, p. 225.

4. W. Austen, "The Influence of Oxygen on Some Properties of Pure Iron," Journal Iron & Steel Institute, 1915, Vol. 92, p. 157.

5. J. R. Cain, "Influence of Sulphur, Oxygen, Copper, and Manganese on the Red Shortness of Iron," Transactions, American Electrochemical Society, 1924, Vol. 46, p. 133.

6. T. D. Yensen, "Iron-Silicon-Carbon Alloys," Journal Iron & Steel Institute, 1929, Vol. 120, p. 187.

7. C. H. Herty, Jr., B. M. Larsen, V. N. Krivobok, R. B. Norton, R. E. Wiley, A. W. Sikes and J. E. Jacobs, "Abnormality in Case Carburized Steels." Cooperative Bulletin 45, U. S. Bureau of Mines, Carnegie Institute of Technology, and the Metallurgical Advisory Board, 1929.

8. C. H. Mathewson, E. Spire and W. E. Milligan, "Evolution of the Iron-Oxygen Constitutional Diagram." To be published in the Transactions of the American Society for Steel Treating, fall of 1931.

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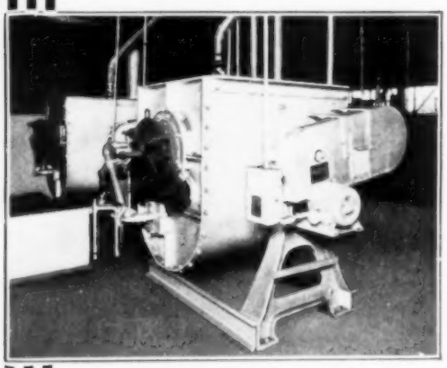

MANY are the outstanding advantages of this type of furnace in carburizing stock that may be slowly tumbled in granular compound, within safe limits and grinding and surface condition.

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Chromium Plating Technique

(Cont. from page 59) plate removed in grinding has been set at 0.003 in. on the diameter of a round piece. Grinding is being done with the same wheels used for hardened steel, although a lighter cut is taken and the time required is from 1½ to 2 times as long. The wheel must also be dressed more frequently. Considerable heat is generated in the process, as evidenced by the intense white spark; plenty of coolant is necessary. Extreme accuracy is obtained by lapping. A piece of work which was checked in grinding is shown in the illustration on page 58.

Except that it is file hard no definite measure has been attempted of the hardness of the plate applied under the particular conditions existing at Phillipsburg. It may be said, however, that service reports on plated parts are most often three to one as compared to hardened steel. This relation represents the comparative resistance to abrasive wear.

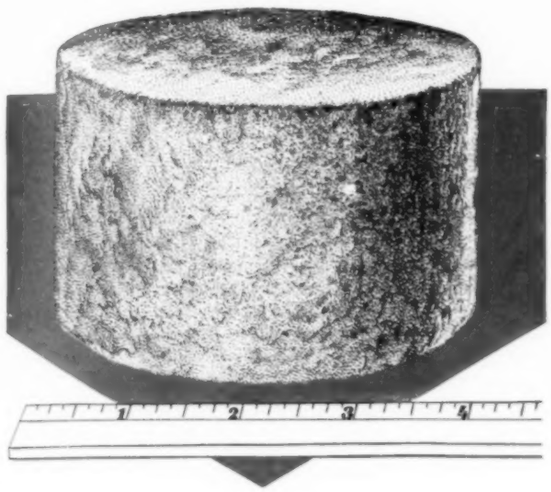
One is easily impressed with the truth that chromium is hard. Its greasy "feel" also recommends it for rubbing surfaces. However, assurance that the plate will not peel or chip is not so easily obtainable.

That the desired adherence can be obtained is evidenced by the satisfactory performance of such plated jobs as centerless grinder workrests and drill jig bushings. Page 59 pictures a plate 0.007 in. thick which was purposely dented; observe that the plate did not "jump off." One application to drill bushings has been found exceptionally fortunate, when close spacing requires a wall thickness so light as to raise a difficult problem in the hardening room.

By using chromium on a wide variety of shop repair jobs a considerable fund of information is being built up which includes data upon the action of the plate on many types of service. This includes tool slides, boring bars, milling arbors, shaper crossheads, grinder spindles, shafts and plungers of various kinds. Before regular application is made to any part of the Ingersoll-Rand's product adequate service tests are carried out. From data collected so far it appears that chromium plating is a process which must be very carefully handled, but for which there is a wide application in parts which must resist abrasion.

E. M. Silicon Briquets...

What they are—What they do



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1. Assure higher silicon recovery.
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3. Permit better control of chemical analysis, hardness and machinability.
4. Give more uniform strength in castings of irregular cross-section.
5. Insure greater freedom from large graphite flakes.
6. Reduce objectionable sulphur and phosphorus in the charge.
7. Lower loss by reducing number of scrap castings.
8. Silicon in concentrated alloy is more effective as deoxidizing agent.
9. The 2½ lb. briquet contains exactly 1 lb. of metallic silicon. The 5 lb. briquet contains 2 lbs. of metallic silicon.

E. M. SILICON BRIQUETS assure uniformly high physical properties in gray and high test iron because they give the foundryman absolute control of the silicon charge in the cupola.

Each **E. M. SILICON BRIQUET** contains a definite amount of metallic silicon, which a cement binder protects from oxidation until it reaches the melting zone. Here, only pure silicon is released to the iron, and the binder passes off with the slag. As a result, silicon recovery is higher, and castings uniform in physical and chemical analysis are produced.

E. M. SILICON BRIQUETS will give you better castings at lower cost. Electromet Engineers will be glad to answer your inquiries on this subject.

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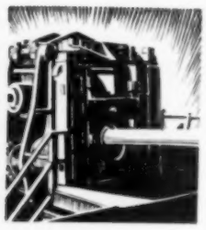
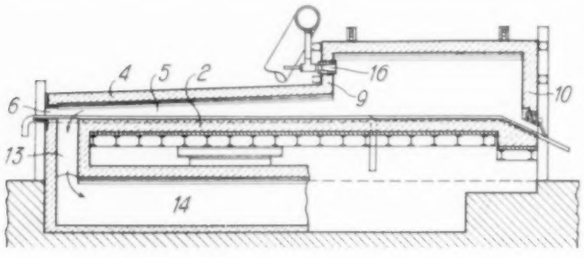


Reviews of Recent Patents

By Nelson Littell
Patent Attorney
22 East 40. Street
New York City
Member A. S. S. T.

Heating Furnace, *by Albert L. Culbertson, Mount Lebanon, Pa. 1,789,966; Jan. 27.*

This furnace provides a vertically disposed horse-shoe shaped body of flame above the material being heated at the exit or discharge end of the furnace so that the flame is hottest at the back or entering end of the combustion chamber. The hearth 2 has a low enclosing structure *4* from the rear or entering end and forms a low channel portion *5*. The rear end of the structure *4* is provided with an opening *6* through which the material to be heated is charged into the furnace. A vertical flue *13* is also provided at the rear connecting with the horizontal flue *14* adapted to supply a regenerator for preheated air to the furnace burners. The rear wall *9* of the combustion chamber *8* is provided with oil burners *16*, and the flame from the burners will be forced steadily in a substantially horizontal plane through the upper portion of the combustion chamber until it strikes the forward wall *10* of the chamber which will force the flame body to turn downwardly toward the furnace hearth and then rearwardly to escape in a direction opposite to that of the movement of whatever material is being heated in the furnace at the time.



Open-Hearth Steel, *by Alexander L. Feild, Canton, Ohio, assignor to Republic Steel Corp. 1,794,068; Feb. 24.*

The removal of carbon during refining is caused to take place at that rate which obtains a product characterized by maximum cleanness and freedom from non-metallic inclusions. The invention particularly relates to a more satisfactory control of the iron oxide which is carried out by an application of mathematical formulas which may be defined as a determination of the iron oxide according to the following equation: $dx/dt = .0000757\ kw\ (1.08 - 1/x)$; in which dx/dt is the desired rate of carbon elimination and k is a constant, w is the percentage of FeO in the slag and x the coincident percentage of carbon in the bath at time t, the constant percentage of iron oxide being maintained by determining the iron oxide content of the slag from time to time in the course of the refining, and adjusting such content whenever this course becomes necessary during the various stages in the process of refining the molten steel.

(Continued on page 106)

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The Cleveland Steel Products Corp., Cleveland, Ohio, manufacture Universal Drive Shaft Joints of the highest grade, which are now being carburized in the Electric Vertical Carburizer. Certain portions of the joints must be protected against carbon penetration which is effected by copper plating the surfaces that must be retained soft for machining. By using Carbonal, complete protection is acquired, neither carbon penetration nor copper migration occurring. The product is uniformly excellent and the operating cost exceptionally moderate.

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Electrode, *by Arthur Percy Strohmenger, London, England, assignor to Quasi-Arc Inc., New York. 1,794,042; Feb. 24.*

This invention contemplates a substitution for an electrode's usual mild steel cores which are unsatisfactory when subject to stresses at high temperatures. In order to obtain a homogeneous weld metal offering a high resistance to corrosion it has been found that it is necessary to introduce additional manganese into the core of the electrode. The coefficient of expansion for changes of temperature is at a minimum between 0.4% and 0.5% of manganese, and many physical properties appear to undergo a change within this range. The percentage of manganese required in the metal forming electrode by the arc welding process is in the neighborhood of .45%. The physical properties of the deposited metal are also improved not only when under stress at normal temperatures, but also when stressed to a condition of strain at the higher temperatures about 900° C., as for example when forging or otherwise deforming the metal. A certain percentage of silicon can also be introduced with advantage as it tends to reduce the loss of manganese during deposition. The preferable formula for the core is one that contains a quantity of manganese depending upon its diameter and varying inversely as the diameter from 2.25% to 4% for cross-sections of electrode cores from 0.042 to 0.005 sq.in.

Electric Induction Furnace, *by Edwin Fitch Northrup, of Princeton, New Jersey, Assignor to Ajax Electro-thermic Corporation, of Ajax Park, New Jersey. 1,795,136, March 3.*

Currents of normal frequency are supplied to the coil of this furnace by transformers having a number of secondary windings which have both an individual and a combined inductive action on the charge, the effect of which is to produce a wave of magnetism which will travel from top to bottom or from bottom to top of the charge. The inductor is free from inclusion of transformer iron and has a common source of energy for each of the separate inductor coils in the furnace.

(Continued on page 108)

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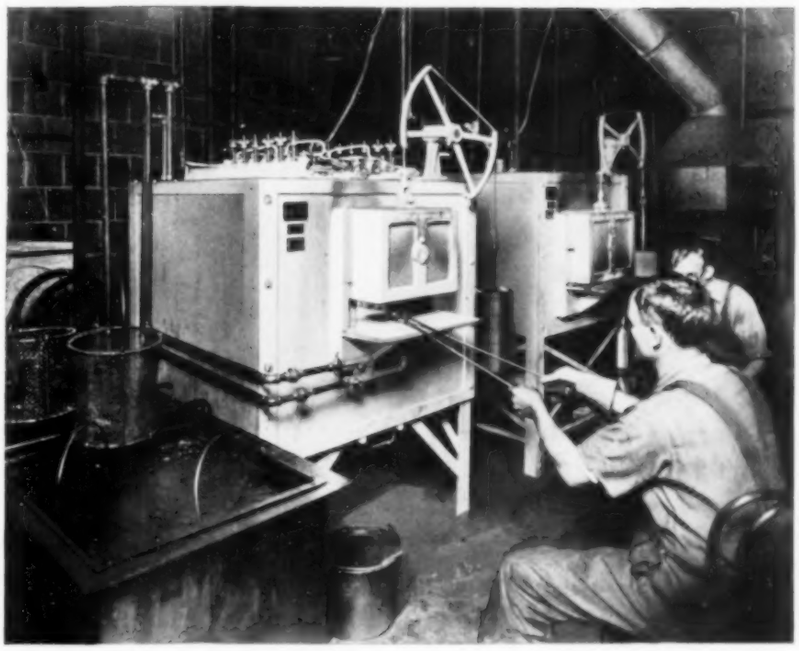

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Copper Alloy, *by Michael G. Corson, Jackson Heights, N. Y., assignor of Three-Twentieths to George H. Corey, Bayside, N. Y. 1,792,146; Feb. 10.*

The alloys covered by this patent consist principally of copper, tin, and zinc, and are characterized, when properly treated, by properties giving them special utility when used in forming lubricated wearing surfaces. Such alloys of the tin bronze group have a soft ground mass serving as a matrix for a second constituent, the delta phase, of considerable hardness and possessing good bearing qualities. It has been found that ternary bronzes can be made to behave much like complex brasses, alpha plus beta, in their ability to be hot worked when brought into the beta state and to retain a high strength with considerable ductility in the cold state. Such alloys can be prepared within the following range of proportions: Tin, 4–18%; zinc, 10–35%; balance of copper. The amounts of zinc and tin depend upon each other. The more zinc the alloy contains the less tin it may contain. Small amounts of nickel, preferably around 3%, may be substituted for an equal amount of copper, and either a part of the tin, or the zinc may be replaced by about half its weight of aluminum. These alloys can be used as cast or be forged, rolled or extruded.

Cementation Process, *by Hermann Freudenberg, Frankfort-on-the-Main, Germany, assignor, to the Roessler & Hasslacher Chemical Co. 1,796,248; March 10.*

The cyaniding of iron is very effective when finely divided carbon is the cementing material. The cementing temperature depends upon the depth of cementation desired. In one typical operation a bolt of low carbon iron was heated to 950° C. for two hours in a fused bath of soda and sodium chloride containing 1% of very finely milled wood charcoal. The bolt was then quenched. The hardness of the bolt was increased by this procedure from 13 on the Rockwell scale to 42 Rockwell, whereas in a fused salt bath of the same composition but free of carbon, the same kind of a bolt heated under identical conditions showed a hardness of only 20 Rockwell.

(Continued on page 110)

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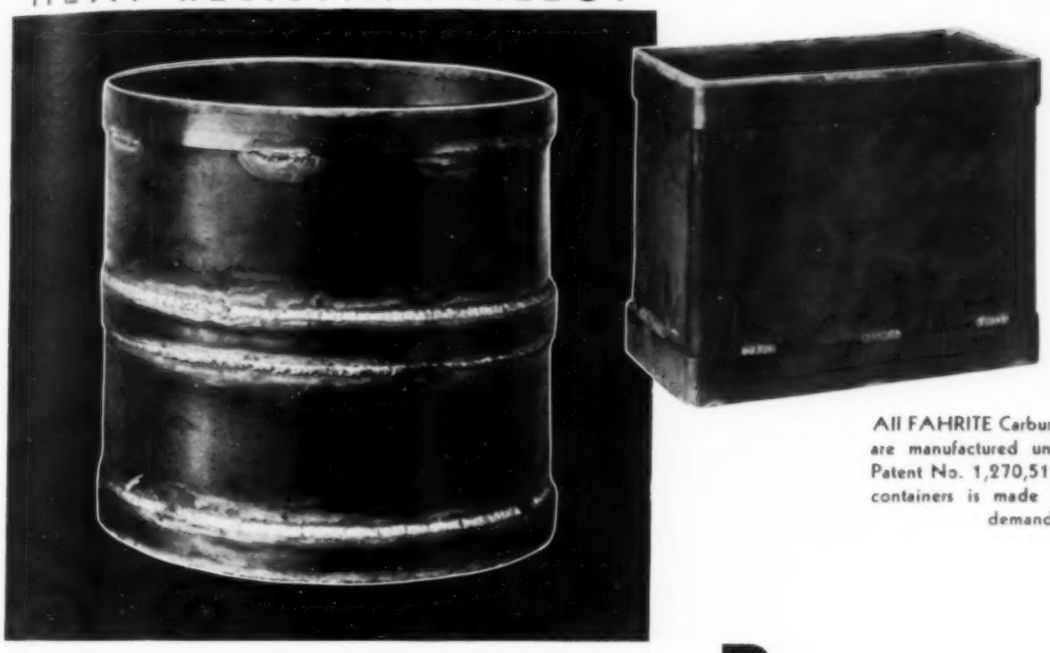

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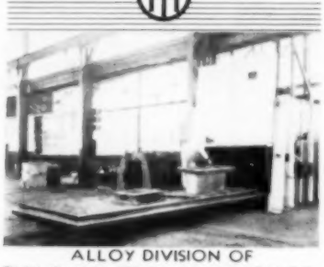

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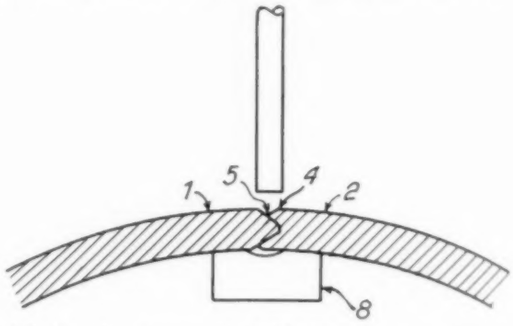
Localized Hardening, *by James Carey Davis, Chicago. 1,794,445; March 3.*

It is best to apply localized hardening to cast steel car wheels containing manganese in which the uniform hardening of the wheel treads is important so that the wheel may wear both uniformly in surface and not lose its circular character, and also that the hardening be localized at the tread and throat, most usually in contact with the rail head. This method of tempering consists of heating and maintaining the temperature of the car wheel, casting above the critical range, quenching a localized area of the peripheral surface adjacent to the heel by the application of a quenching fluid, omitting portions of the tread between the heel and flange, withdrawing the quenching fluid and permitting reheating of the localized area from the main body of the casting and then quenching the entire peripheral surface before the casting is cooled below the critical range. The result of the various steps is that the car wheel has a main tread or wearing surface of great hardness, and at the same time the heel or outside of the treated portion of the rim is softer and more ductile, and therefore is much stronger under impact and will wear more uniformly.

Pipe Welding, *by Howard J. Burnish, Milwaukee, 1,794,363; March 3.*

In this process the edges *1* and *2* of the pipe are provided with a tongue and groove interlock, the outer corner *4* of the edge *2* preferably being cut away to provide a groove *5* along the seam to be



welded. A grooved chill block *8* molds the lower parts of the edges and prevents injury due to the high concentration of heat. The interlocking of the edges alines the seam and allows the application of pressure as well as excludes air and other contaminating elements.

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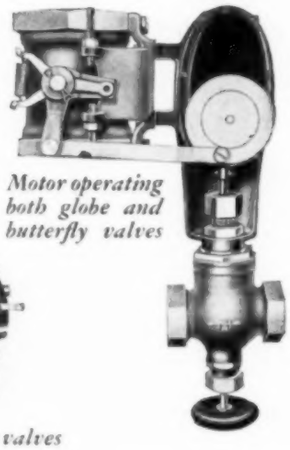
These Castings *look alike*

but their production is two different stories



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Type V-30 gas valves for low pressure gas

Temperature controller

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Both made the grade with the customer's inspector. Both check out in every critical dimension. Both are quality castings—free from flaws and defects. In other words, they are alike.

But their histories are *not* alike.

No. 1 was produced in a shop where core baking, heat treating and annealing temperatures are governed by hand and eye. Its history is one of lost time and resultless effort, of wasted materials now reposing on the spoil pile. Though the specifications were finally met—the profits leaked by the wayside.

No. 2 comes from a plant no more modern than the birthplace of No. 1—except for one thing: automatic control of temperatures.

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In the preparation of the Metallurgical Index by the staff of the American Society of Mechanical Engineers some 1800 domestic and foreign technical publications are regularly searched. From this material the A.S.S.T. is supplied with this selective index to those articles which deal particularly with steel treating and related subjects.

Metallurgical Index

ALUMINUM ALLOYS

Les alliages légers et leur traitement (Light Alloys and Their Treatment), Simmonnet. *Revue de l'Industrie Minérale*, no. 247, Apr. 1, 1931, pages 122-128.

Account of author's experiences with forging and heat treating light alloys for automobile parts and aircraft engines; influence of different constituents; explanation of phenomena of hardening and aging; casting and forging light alloys; hardening and annealing; welding of treated alloys; corrosion; study to alloys with aluminum base.

Aluminiumguss in Dieselmotorenbau (Aluminum Castings in Diesel Engine Design), W. Hartl. *Automobiltechnische Zeit.*, vol. 34, no. 4, Feb. 16, 1931, pages 94-98, 31 figs.

Practical examples illustrate proper utilization of light metals in highly stressed castings; data on physical properties and methods of reducing notch effect.

The Effect of Artificial Ageing Upon the Resistance of Super-Duralumin to Corrosion by Sea-Water, K. L. Meissner. *Inst. Metals—Advance Paper*, no. 557, Mar. 11-12, 1931, 15 pages, 12 figs.

Corrosion tests were carried out in North Sea between high and low watermarks with strips of superduralumin, 2 mm. thick (duralumin containing 0.8 per cent silicon) for 3 months.

BRASS

Deep-Etch Test of Brass, W. F. Graham and L. A. Meisse. *Am. Foundrymen's Assn.—Trans.*, vol. 2, no. 2, Feb. 1931, pages 810-822 and (discussion) 822-825, 5 figs.

Result of deep-etch test of cast red brass, using nitric acid as reagent; test reveals not only inclusions and character of metal from oxidized or reduced standpoint, but also porosity, laminations or actual fissures which are not visible to eye in unattacked fracture.

The Metal Arc Welding of Copper Alloys, I. T. Hook. *Am. Welding Soc.—Jl.*, vol. 10, no. 4, Apr. 1931, pages 31-37, 4 figs.

Effect of impurity in base metals and metal arc electrodes; fluidity of copper alloys; high electrical conductivity connections; metal arc welding of brass, phosphor bronze, ambrac and everdur.

Die Pressing of Brass and Copper Alloys, J. R. Freeman, Jr. *Am. Inst. Min. Met. Engrs.—Tech. Pub.*, no. 391, Feb. 1931, 8 pages, 9 figs.

Die pressing is defined as method of producing irregularly shaped parts by hot deformation in die under pressure; details of modern technique of making die pressing of brass and copper alloys; importance of die design; adjustment of temperature of pressing; finishing pressings and preparing for shipment.

CAST IRON

Die zeichnerische Auswertung des Biegeversuchs (Graphic Evaluation of Bending Tests), R. Mitsche. *Giesserei*, vol. 18, no. 12, Mar. 20, 1931, pages 246-247, 4 figs.

Generally applicable method of determining bending strength by graphic means.

Effects on Cast Iron of Prolonged Heating at 800-1100 Degs. Fahr., R. S. MacPherran and R. H. Krueger. *Am. Foundrymen's Assn.—Trans.*, vol. 2, no. 2, Feb. 1931, pages 826-855 and (discussion) 855-863; also author's closure, pages 863-864, 16 figs.

Various types of cast iron were heated for 500 hrs. at temperatures up to 1100 deg. fahr., after which physical and chemical tests were made to determine effect; high silicon materially accelerates decomposition of pearlite, and nickel does same, although to lesser extent; low silicon and low carbon with finely divided graphite flakes tend to delay this action; chromium increases tensile strength at room temperatures and delays decomposition of pearlite.

Some Phases of Heat Treatment of Cylinder and Alloy Irons, F. J. Walls and A. Hartwell, Jr. *Am. Foundrymen's Assn.—Trans.*, vol. 2, no. 3, Mar. 1931, pages 865-890 and (discussion) 890-896, 16 figs.

Relief of stresses and physical changes of cylinder irons by various heat treatments, with particular regard to chromium-molybdenum and chromium-nickel-manganese cast irons; to obtain maximum relief of stresses and minimum of growth and changes in hardness, heat at 950 deg. fahr. and follow by slow cooling; microphotographs illustrate structural characteristics after various heat treatments.

MALLEABLE. Unified Methods of Producing Malleable Cast Iron, S. S. Nekriti. *Vestnik Metallopromyshlennosti*, no. 6, June 1930, pages, 78-97, 34 figs.

Report on experimental study, made at Lyudinov iron works on casting of nipples and their treatment; study of chemical and microstructural changes; testing of wedge shaped specimens of malleable cast iron.

Festigkeit und Wandstaerke bei Gusseisen (Strength and Wall Thickness of Cast Iron), A. Heller. *Giesserei*, vol. 18, no. 12, Mar. 20, 1931, pages 237-241, 4 figs.

Review of literature dealing with relation between strength and thickness of cast iron; comparison of experimental results shows possibility of setting up in near future diagram for strength of cast iron, from which certain properties of cast iron can be predetermined; such a diagram is presented.

Fatigue Stresses, with Special Reference to the Breakage of Rolls, F. Bacon. *Engineering*, vol. 131, nos. 3397 and 3399, Feb. 20, 1931, pages 280-282 and Mar. 6, pages 341-344, 6 figs.

Laboratory fatigue tests; fatigue properties of cast irons; fatigue stresses in bottom roll; fatigue failure of laterally loaded shaft; hair cracks in fatigue fractures; classification of fatigue fractures according to hair crack contours; transverse bending of cast iron; influence of roll diameter on breakage; influence of depth of chill; running strength of rolls. Before S. Wales Inst. Engrs.

COLD WORKING

The Manufacture of Cold Drawn Steel, E. D. Townsend. *Rolling Mill Jl.*, vol. 5, no. 3, Mar. 1931, pages 195-200 and 204, 5 figs.

Methods and principles employed in cold drawing steel bars, wire and tubing; applications of such products.

Physical Values Assist in Specifying Cold Strip—II, J. S. Adelson. *Steel*, vol. 88, no. 12, Mar. 19, 1931, pages 40, 42-43 and 46, 4 figs.

(Continued on page 128)

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Physical values representative of commercial tempers and based upon test of low-carbon product.

Cold Working Followed by Annealing, R. L. Geruso. *Heat Treating and Forging*, vol. 17, no. 2, Feb. 1931, pages 139-142, 1 fig.

Survey of researches by European and American authorities including Jefferies and Archer, French and Tucker; study of effect of annealing at temperatures ranging from 0 to 600 deg. cent. on physical properties, tension, Rockwell, bend and impact tests of 0.22 per cent and 0.89 per cent Mn steel, cold worked 4, 6, 8, 12, 16 and 20 per cent respectively.

CORROSION

Werkstoffe Physikalische Eigenschaften und Korrosion, E. Rabald. Leipzig, Otto Spamer, 1931, 2 v., illus., tables, 128.-r.m., bound 135.-r.m.

Remarkable summary of literature on corrosion of metals and non-metals; author has examined material published between 1897 and 1929, and gives salient facts in brief form, with references to sources; bibliography contains about 10,000 items; index by attacking agents is included, enabling proper materials for any purpose to be found quickly. Eng. Soc. Lib., N. Y.

Korrosionsbestaendigkeit von Chrom-Nickel-Eisen-Legierungen (Anti-Corrosion Qualities of Chrominum Nickel Iron Alloys), E. Wellman. *Zeit. fuer Elektrochemie*, vol. 37, no. 3, Mar. 1931, pages 142-156, 16 figs.

Series of chemical tests and analysis. Bibliography.

ELECTRIC FURNACES

Electric Annealing of Aluminium. *Foundry Trade Jl.*, vol. 44, no. 763, Apr. 2, 1931, page 244, 1 fig.; see also *Metal Industry (Lond.)*, vol. 38, no. 14, Apr. 3, 1931, page 364, 3 figs. and *Mech. World*, vol. 89, no. 2310, Apr. 10, 1931, page 343.

To facilitate precise annealing of aluminum sheets on large scale, General Electric Co. has installed large single-track multi-car type electric annealing furnace which has effective hearth area 24 ft. long by 7 ft. 5 in. wide in works of Aluminum Corp., Dolgarrog, Carnarvonshire; furnace has electric loading of 150 kw., heating elements arranged to ensure phasal balance on 440-volt, 3-phase, 50-cycle supply.

A New Cyanide Furnace, R. F. James and G. Coley. *Franklin Inst.—Jl.*, vol. 212, no. 3, Mar. 1931, pages 327-334, 3 figs.

Furnace was placed on trial in plant of Gemmer Manufacturing Company of Detroit for life test under operating conditions; this service was as severe as any cyanide pot service because of heavy production required from these pots; they are used for hardening steering gear sectors and maximum production is required.

Electric Heating Insures Quality Production. *Elec. World*, vol. 97, no. 15, Apr. 11, 1931, pages 680-681, 3 figs.

After considering advantages of gas, oil and electricity, electricity was decided on at Pratt & Whitney Aircraft Corp.; reasons for choice of electricity are outlined.

Bright Anneals in Artificial Atmospheres, J. C. Woodson. *Elec. Jl.*, vol. 38, no. 4, Apr. 1931, pages 246-247, 3 figs.

Possibilities of annealing in artificial atmospheres, which process is still in development stages, are not known; however, certain surface conditions can be obtained that reduce number of subsequent operations and greatly increase die life and reduce machine work; various types of electric furnaces are illustrated.

Elektrische Gluehanlagen in Metallwerken (Electric Heat Treatment Furnaces in Metal Plants), K. Tamele. *V.D.I. Zeit.*, vol. 75, no. 13, Mar. 28, 1931, pages 383-387, 12 figs.

Brief description of various designs of electric resistance furnaces and their operating characteristics; general considerations regarding design and selection.

HEAT TREATMENT

Beitrag zur Wirtschaftlichen Waermebehandlung des Stahles (Economic Heat Treatment of Steel), E. Bock. *Maschinenbau*, vol. 10, no. 4, Feb. 19, 1931.

(Continued on page 130)

The Burning Question?

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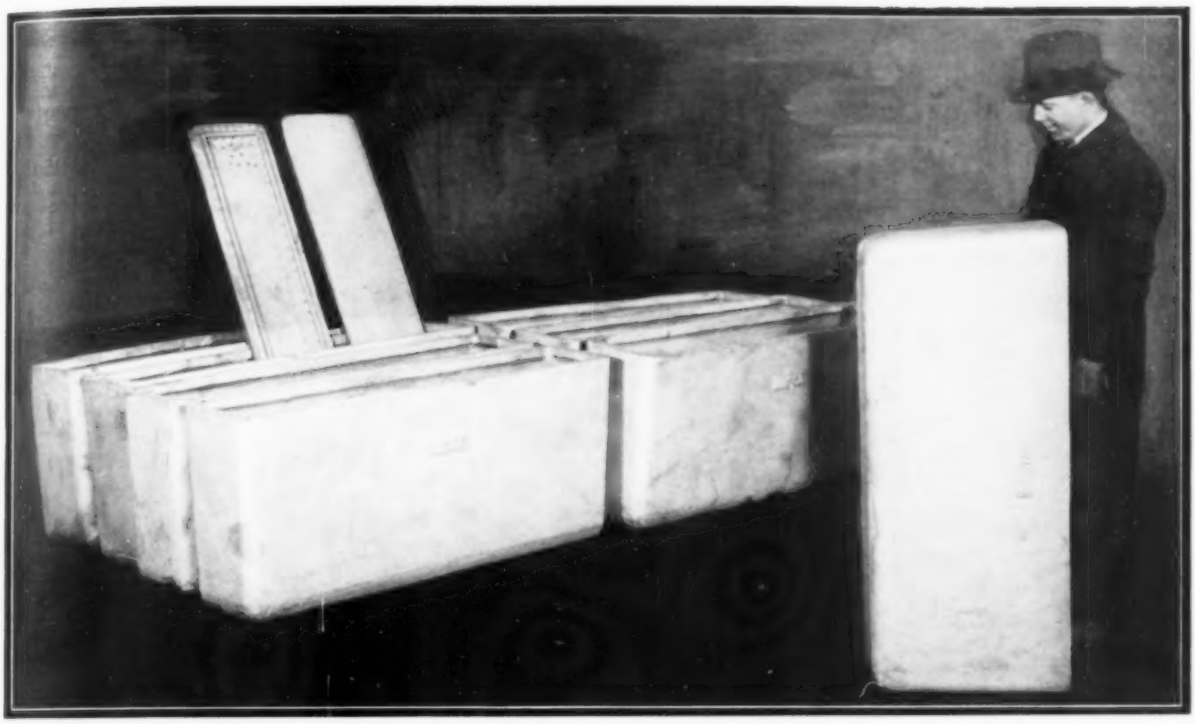

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Methods of improving quality of product and reducing cost of heat treatment by application of known tempering and hardening processes; data on quenching media and hardness obtainable with different types of steel; microphotographs illustrate effect of treatment on crystal structure.

Le procédé grunewald de recuit en blanc (Grunewald Process of Bright Annealing), R. W. Meunier. *Revue Universelle des Mines*, vol. 5, no. 4, Feb. 15, 1931, pages 102-106, 7 figs.

Economic advantages of Gruenewald process; method of annealing; metal is annealed uniformly at most favorable temperature and without trace of oxidation.

Continuous Bright Annealing of Steels in Hydrogen, F. C. Kelley. *Fuels and Furnaces*, vol. 9, no. 3, Mar. 1931, pages 303-304, 1 fig.

Fundamental principles involved in continuous bright annealing of stainless irons and low carbon steel sheets. Before Am. Inst. Min. and Met. Engrs.

The Effect of Various Annealing Temperatures on Cold Worked Low Carbon Steel. *Mich. Eng. Experiment Station—Bul.*, no. 35, Mar. 1931, pages 3-17, 22 figs.

Results of experiments made to determine best temperatures for annealing cold-worked low-carbon steel; it was found in general that best annealing temperature lay just below lower critical point; steel that is annealed above critical range unless cooled very slowly, is not in as perfectly annealed condition as one annealed at 1250 deg. fahr.; annealing temperatures below 1000 deg. fahr. were not found satisfactory.

Veredelung mechanisch vorbehandelter Bleche durch ein neues Verfahren der Warmbehandlung (Improving Mechanically Preheated Sheet by New Method of Heat Treatment). *Zeit. fuer die Gesamte Giessereipraxis*, vol. 51, no. 45, Nov. 9, 1930, *(Metall)* pages 183-184; see also brief translated abstract in *Inst. Metals—Jl.*, vol. 47, pt. 3, Mar. 1931, page 173.

Method suggested consists in annealing metal at fixed temperature, not less than maximum previously attained, for 30 min. only; marked improvement in mechanical properties was obtained for brass and aluminum alloys.

New Carburizing Bath Affords Increase in Depth of Case, E. C. Moffett. *Steel*, vol. 88, no. 11, Mar. 12, 1931, pages 38-40 and 42, 3 figs.

Hardening steel in bath of sodium cyanide largely has been confined to case depths under 0.010 in.; limitations, however, have been removed by salt bath composed of sodium and calcium chlorides and activating ingredient. Before Am. Soc. Steel Treating.

METALLOGRAPHY

CEMENTITE. Investigation of Action of Cementite Solution in Carbon Steel and Influence of Heterogeneity of Material on Same (Undersokning rorande mekanismen vid cementitens losning hos kolstal, etc.), E. Walldow. *Jernkontorets Annaler (Stockholm)*, vol. 85, no. 8, 1930, 377-431, 81 figs.

Phenomena occurring when alpha-steel changes to gamma-steel with simultaneous dissolution of cementite; change occurred on different parts of test piece and at different temperatures, this has been compared with occurrence of unevenly distributed impurities in technical steel; attempt is made to prove that silicon has effect on impurity.

STRUCTURE. Grain Refinement. *Metallurgist (Supp. to Engineer, Lond.)*, Oct. 1930, 146-147.

Researches have led to general idea that fine grain size implies superior quality and properties and that coarse grain is always undesirable, but it seems that in certain cases it is coarser rather than finer structure that affords longest resistance to gradual flow and rupture; what is needed is deep-going research on whole process of solidification with object of providing better basis of scientific knowledge of process.

METALLURGY

Der longitudinale thermomagnetische Potentialeffekt (Longitudinal Thermomagnetic Potential Effect), J. Zahradnicek. *Zeit. fuer Physik*, vol. 66, no. 5-6, Dec. 3, 1930, pages 425-430, 3 figs.; see also brief translated abstract in *Inst. Metals—Jl.*, vol. 47, pt. 3, Mar. 1931, pages 133-134.

Longitudinal thermomagnetic potential effect refers to fact that potential drop in wire heated, say, by electric current, is changed when wire is subjected to action of transverse magnetic field; phenomenon is best shown by ferromagnetic metals; two methods of investigating phenomenon are described.

Gases in Metals, C. J. Smithells. *Metal Industry (Lond.)*, vol. 38, no. 10, Mar. 6, 1931, pages 261-264 and 268, 3 figs.

Adsorption of gases by metals; solubility of hydrogen in various metals; nitrogen; gases extracted from copper at 1250 deg. cent.; gas extracted from nickel at 1470 deg. cent.; vacuum melting; presolidification; tin, aluminum and brass; nitrogen treatment; chlorine treatment. Before Inst. Metals.

Diagram of Iron-Manganese Alloys, V. N. Krivobok. *Heat Treating and Forging*, vol. 17, no. 2, Feb. 1931, pages 153-154, 2 figs.

Theory and fact in construction of constitutional diagram.

Characteristics of Rimmed Steel—II, E. C. Bitzer. *Blast Furnace and Steel Plant*, vol. 19, no. 3, Mar. 1931, pages 415-417 and 422, 1 fig.

Relation of various factors determining quality of product; iron oxide-iron carbide reaction; table gives data on proper temperature for rimming steel; segregation phenomena.

Les méthodes industrielles rapides de dosages et d'analyses métallurgiques (Rapid Industrial Methods of Metallurgical Analysis), G. d'Ardigny. *Fonderie Moderne*, vol. 25, Jan. 25, 1931, pages 31-33, 3 figs.

Review of standard methods and apparatus used in analysis and compounding of samples.

Texture of Metals After Cold Deformation, F. Wever. *Am. Inst. Min. and Met. Engrs.—Preprint*, for mtg. Feb. 1931, 25 pages, 33 figs.

Résumé of earlier investigations with X-ray; camera apparatus for reflection projection; texture of cold-deformed metals; résumé of study of cubic metals; texture of cold-compressed metals and of cold rolled metals; texture with plane parallelepipedal compression; analysis of textures; deformation texture; body-centered cubic metals; correlation with rolling process. Bibliography.

New Manganese-Silicon Alloys for the Deoxidation of Steel, C. H. Herty and G. R. Fitterer. *U. S. Bur. Mines—Report of Investigations*, no. 3081, Feb. 1931, 14 pages, 3 figs.

Major object of series of investigations on deoxidation was to find deoxidizing material which would thoroughly deoxidize steel bath, and in this deoxidation would form reaction products which were fusible at steel making temperatures and which would coalesce with one another to form very large inclusions with resultant quick cleaning of metal; some of manganese-silicon alloys described in this paper fill functions of such deoxidizing material; major results of deoxidation with manganese-silicon alloys.

Zur Deoxydation des Stahls mittels neuer Mangan-Silizium-Legierungen (Deoxidation of Steel by Means of New Manganese-Silicon Alloys). *Metallboerse*, vol. 21, nos. 25 and 29, Mar. 28, 1931, pages 580-581, and Apr. 11, pages 676-677, 1 fig.

Oxide inclusions and their removal; three different deoxidation methods for obtaining best composition of inclusions composed of iron oxide, manganese oxide and silicic acid; composition of manganese-silicon alloys used in these tests.

French Versus American Sheet Steel, E. S. Lawrence. *Heat Treating and Forging*, vol. 17, no. 2, Feb. 1931, pages 133-136 and 138, 8 figs.

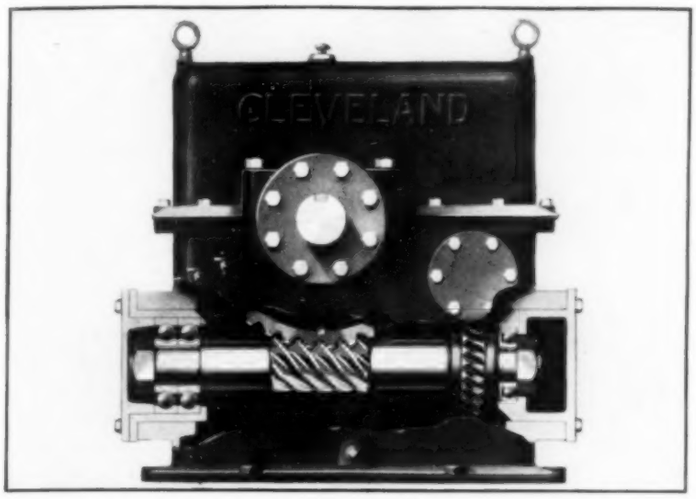
Study of full finished, deep drawing sheet manufacture in sheet mills of France and its comparison with methods utilized in United States; data on composition and crystal structure of steel. (Continuation of serial.)

A Highly Sensitive Device for Measuring Stresses and Deflections, J. Hedberg. *Civil Eng. (N. Y.)*, vol. 1, no. 6, Mar. 1931, pages 540-541, 1 fig.

Measurement is accomplished by reading galvanometer recording fluctuations in plate current of vacuum tube, caused by changed capacity of manometer condensers in resonant oscillating circuit; manometer with air between plates found capable of measuring accurately movements of 0.0000002 in., producing straight line relationship between deflection and galvanometer reading.

(Continued on page 132)

POWER



Left: Double reduction unit with 1% Nickel bronze gears. Mfd. by Cleveland Worm & Gear Co. Below: 80' 1000 lb. chain draw bench with Cleveland worm gears.

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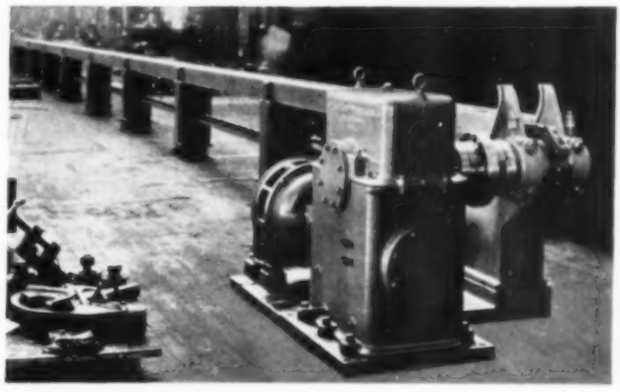
Nickel bronze worm gears are well nigh standard for speed reducing units and other equipment where a steady flow of power must be transmitted through gears.

This is one more example of how Nickel can be alloyed with other metals to secure a definite improvement in physical properties. Additional details are contained in our publication "Some Effects of Nickel in Bronze Foundry Mixtures".



Nickel alloyed with other metals—steel, stainless steel, iron, brass, bronze, aluminum, etc.—insures dependable mechanical properties and one or more of the following improvements: (1) Greater impact and fatigue strength. (2) Greater resistance to heat, corrosion and wear. (3) Better workability. (4) Improved color and appearance.

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The Deformation of Metals Under Prolonged Loadings—The Flow and Fracture of Aluminum—I, D. Hanson and M. A. Wheeler. *Inst. Metals—Advance Paper*, no. 554, for mtg. Mar. 11-12, 1931, 29 pages, 28 figs.

Experimental work carried out with view to studying mechanism of flow and fracture under prolonged loads; author's observations have bearing on theory of slip and rupture put forward by Gough, Hanson, and Wright.

Some Notes on Blue Brittleness. L. R. Van Wert. *Am. Inst. Min. and Met. Engrs.—Tech. Pub.*, no. 404, for mtg. Feb. 1931, 11 pages, 5 figs.

Experimental observations on departure from normal regularity of stress-strain diagrams of low-carbon steels tested within temperature range of 200 to 350 deg. cent.; significance of steps in terms of torsional strain; cause of steps. Bibliography.

The Carbon-Oxygen Equilibrium in Liquid Iron, H. C. Vacher and E. H. Hamilton. *Am. Inst. Min. and Met. Engrs.—Tech. Pub.*, no. 409, for mtg. Feb. 1931, 13 pages, 2 figs.

Attempt is made to determine value of carbon-oxygen product over wide range of concentrations; in earlier stages of work, values of 0.0066 at 1580 deg. cent. and 0.0055 at 1600 deg. cent., were obtained for carbon-oxygen product; these results were obtained by selection of values; variation was great; subsequent experiments, under better control produced value of 0.0025 for product of concentrations of carbon and oxygen in liquid iron at 1620 deg. cent. and 1 atmos. pressure. Bibliography.

Equilibrium in the Iron-Oxygen-Hydrogen System at Temperatures above 1000 deg. C., W. E. Jominy and D. W. Murphy. *Indus. and Eng. Chem.*, vol. 23, no. 4, Apr. 1931, pages 384-387, 2 figs.

Method for determination of iron-iron oxide - hydrogen - water vapor equilibrium at various temperatures has been developed in which gaseous mixture of hydrogen and water vapor is allowed to flow past sample of metallic iron; ratio of hydrogen to water vapor in inlet gases is controlled so that mixture will be either oxidizing or non-oxidizing to iron and at any temperature true equilibrium ratio will lie between closest oxidizing and non-oxidizing points.

METALLOGRAPHY

The Mechanism of the Solution of Cementite in Carbon Steel and the Influence of Heterogeneity, E. Walldow. *Iron and Steel Inst.—Jl.*, vol. 122, no. 2, 1930, pages 301-341, 60 figs. partly on supp. plates.

Study of closer mechanism of solution of cementite, and transformation of alpha iron into gamma iron; most rational way of solving question was considered to be study of few different kinds of steel in detail, instead of extending investigation to include large number of steels. See reference to same article from Jernkonterets Annaler, no. 8, 1930, in Engineering Index 1930, page 1712.

Structural Metallography, H. B. Pulsifer. *Metals and Alloys*, vol. 2, no. 2, Feb. 1931, pages 84-87, 15 figs.

Instructions for proper surfacing and etching procedure with microphotographs illustrating results obtained with various ferrous and non-ferrous alloys; properties and compounding of etching reagents.

Sur les conditions de formation et de décomposition de la cémentite (Conditions of Formation and Decomposition of Cementite), P. Pingault. *Académie des Sciences—Comptes Rendus*, vol. 191, no. 21, Nov. 24, 1930, pages 1007-1008; see also brief translated abstract in *Chem. and Industry*, vol. 50, no. 6, Feb. 6, 1931, page 115.

Pure cementite, prepared by action of sodium cyanide on electrolytic iron filings at 650 deg., is quite stable in vacuum up to 1000 deg.; cementation of pure iron does not occur when heated in sodium cyanide at temperatures up to 900 deg., provided air is absent.

The Metallurgical Microscope. *Metallurgist (Supp. to Engineer)*, Feb. 27, 1931, pages 17-18.

In many modern instruments facility for visual observation is largely sacrificed for convenience in producing photomicrographs; this is almost unavoidable result of following fashion for inverted or "Le Chatelier" type of metallurgical microscope; modern inverted type of metallurgical microscope has many advantages, but there is tendency to ignore its somewhat serious limitations.

Color Etching of Metallic Slides, N. M. Zarubin and G. A. Meyerson. *Vestnik Metallopromyshlennosti*, no. 7-8, July-Aug. 1930, pages 167-173, 3 supp. colored plates.

Report on experimental work done at Electrozavod laboratory; classification of metal etching reagents; color etching of slides of tungsten, steel, iron, ferro-tungsten, and copper; uses of method; color microphotography.

Microscopic Cracks in Heat-Treated Steels, F. F. Lucas. *Mech. Eng.*, vol. 53, no. 4, Apr. 1931, page 295.

Part of paper on Art of Metallography presented at Feb. 1931 meeting of American Institute of Mining and Metallurgical Engineers; significance and control by heat treatment of development of very minute cracks seems to author to be of great practical importance; it seems possible that these cracks may be lines of strain opened by etching reagent.

Die elektrochemische Wiedergabe des Grobgefueges (Electrochemical Reproduction of Coarse Structure), E. Ammermann. *Stahl und Eisen*, vol. 51, no. 7, Feb. 12, 1931, pages 207-208, 5 figs.

Comment on process developed by A. Glazunov, described by him at Eighth Congress of Industrial Chemistry at Strasbourg, July 1928, for development of coarser structure of steel, generally known as macrostructure, with aid of electric current; author suggests certain improvements, recommending use of solution of ferrocyanide instead of partially oxidized ferrocyanide; prints obtained by method are reproduced.

Macro - Printing. *Metallurgist (Supp. to Engineer)*, Mar. 27, 1931, pages 46-47.

Some years ago J. C. W. Humfrey developed method of obtaining what he termed "nature prints" direct from deeply etched surfaces of steel specimens; method suggested by A. Glazunov can be used for detecting segregates and sulphide enclosures in steel; in Stahl und Eisen for Feb. 12, E. Ammermann comments on this process and suggests certain improvements; he recommends use of solution of ferrocyanide instead of partially oxidized ferrocyanide.

The Austenite-pearlite Transformation and the Transition Constitutents, A. Sauveur. *Am. Inst. Min. and Met. Engrs.—Tech. Pub.*, no. 412, 6 pages, 3 figs.; see also *Heat Treating and Forging*, vol. 17, no. 3, Mar. 1931, pages 250-251, 3 figs.

Analytical discussion of current opinion among metallographists; mechanism of transformation of eutectoid steel from its austenitic to its pearlitic condition, on cooling through thermal critical range; claims of some authors, regarding allotropic transformation are considered untenable; various remarks are offered in hope of stimulating discussion and criticism.

Spectroscopy as an Aid in Metallurgical Analysis, S. J. Lewis. *Metallurgist (Supp. to Engineer)*, Feb. 27, 1931, pages 28-30.

In present study spectroscopy has been used merely to elaborate chemical analysis; iron, copper and carbon were subjects of inquiry; arc-spectrum analysis was conducted by means of Hilger quartz spectrograph; examples illustrate value of spectrographic control in discovery of unsuspected elements, detection of various impurities not usually comprehended in chemical analysis, examination of quantitative precipitates for their purity, and in correction of gravimetric figures for proportion of impurities carried by precipitates.

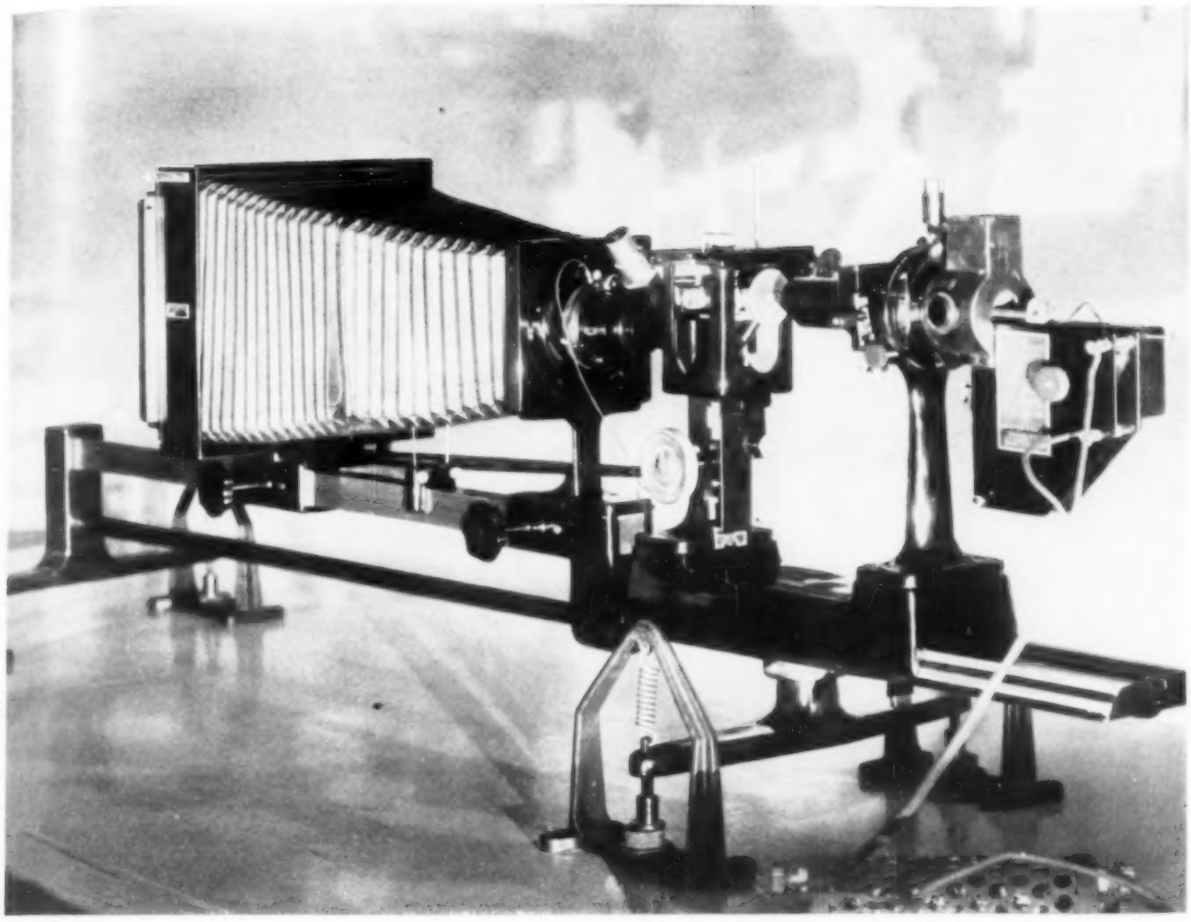
METALS ANALYSIS

New Method for Rapid Analysis of Alloys Without Destruction of the Samples (Nouvelle méthode d'analyse rapide des alliages, etc.), A. Glazunov. *Chimie et Industrie (Paris)*, Mar. 1930, (special no.), 247-250, 9 figs.

Previously described method has been extended to qualitative analysis of metals and alloys; if single metal is present, its nature will be revealed by colored precipitant obtained on paper; it is hoped that by working under definite current density and time conditions approximate quantitative analysis may be obtained from intensity of colors produced.

The Occlusion of Hydrogen and Nitrogen by Pure Iron and Some Other Metals, E. Martin. *Metals and Alloys*, vol. 1, no. 17, Nov. 1930, 831-835, 10 figs.

(Continued on page 134)



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NITRIDING

The Case-Hardening of Commercial Steels by Means of Nitrogen, B. Jones. *Iron and Steel Industry (Lond.)*, vol. 4, no. 3, Dec. 1930, 77-86, and 99, 20 figs.

Investigation of nitridation of 5 austenitic steels of various combinations and variety of plain carbon alloy steels; effect of temperature and of drying ammonia as; increase of hardness. Bibliography.

FURNACES. The Development of a Continuous Nitriding Furnace, R. J. Cowan. *Fuels and Furnaces*, vol. 8, no. 11. Nov. 1930, 1517-1520 and 1552, 7 figs.

Furnace design consists of metal muffle continuous throughout furnace, fired from both sides by gas burners; second furnace consists of alloy pan conveyor type arranged to operate continuously through suitable seals; general layout of continuous nitriding furnace; curves illustrating process operation.

Development of Nitration Equipment (Die Entwicklung der Nitrieranlagen), F. Bruehl. *Kruppsche Monatshefte (Essen)*, vol. 11, Nov. 1930, 287-290, 8 figs.

General viewpoints which are leading in design, presents status of construction and development in principal participating countries.

Problems Confronting the Practical Nitrider, J. H. Higgins. *Iron Age*, vol. 127, no. 14, Apr. 2, 1931.

Practical conditions confronting commercial nitrider with particular regard to selecting, forging and machining steel, nitriding operations equipment, decarburization and its bad effect; ductility of case.

Verhalten nitrierter Sonderstaehle gegen Kupfersulfatloesung (Behavior of Nitrided Steels in Presence of Copper-Sulphate Solution), O. Niezoldi. *Korrosion und Metallschutz*, vol. 7, no. 3. Mar. 1931, pages 53-54, 1 fig.

Based on laboratory tests, it is shown that nitrided special steel is not permanently resistant to copper-sulphate solution.

NON-FERROUS ALLOYS

Recent Developments in Non-Ferrous Alloys. *Machy. (Lond.)*, vol. 37, no. 948, Dec. 11, 1930, 358-360.

Review of principal characteristics and physical properties of light alloys; copper alloys, everdur; P. M. G. metal; aluminum brasses; beryllium alloys; lead and zinc alloys.

Rational Non-Ferrous Foundry Practice (Rationelle Metallgiesserei Praxis. XIV. Die wichtigsten Rezepte und Untersuchungen des Metallgiessers). *Zeit. fuer die gesamte Giessereipraxis (Berlin)*, vol. 51, nos. 49 and 50, Dec. 7, 1930, *(Metall)*, 197-198, and Dec. 14, 202-203.

Most important methods of testing and analysis used in non-ferrous foundries; determination of clay and lime in molding sand; testing core binders; determination of ash content and moisture in coke; determination of sulphur, manganese and iron; in copper alloys; manganese in aluminum alloys; lead in pure tin; testing pure aluminum.

OXYACETYLENE WELDING

Welding Papers from Zurich Congress. *Acetylene Jl.*, vol. 32, no. 4, Oct. 1930, 135-137.

Abstract of papers by A. Desgranges, C. F. Keel, M. Michaud and R. Granjon, dealing chiefly with application of welding to structures, sheet metal, welding machines, brazing and welding of masts and poles.

Safety Engineering Problems in Oxyacetylene Welding (Sicherheitstechnische Fragen beim Azetylenschweissen), E. Sauerbrei. *V. D. I. Zeit. (Berlin)*, vol. 74, no. 46, Nov. 15, 1930, 1591-1595, 16 figs.

Study of explosion hazards and frequency of accidents due to this cause; air elimination in oxyacetylene welding; danger from acetylene-and-air mixtures; welding in freezing weather; backfiring and oxygen hazards; vacuum-water seal safety systems.

MACHINES. Gas Welding Machines in Germany, K. P. Berthold. *Welding*, vol. 1, no. 12, Oct. 1930, 815-819, 8 figs.

(Continued on page 136)

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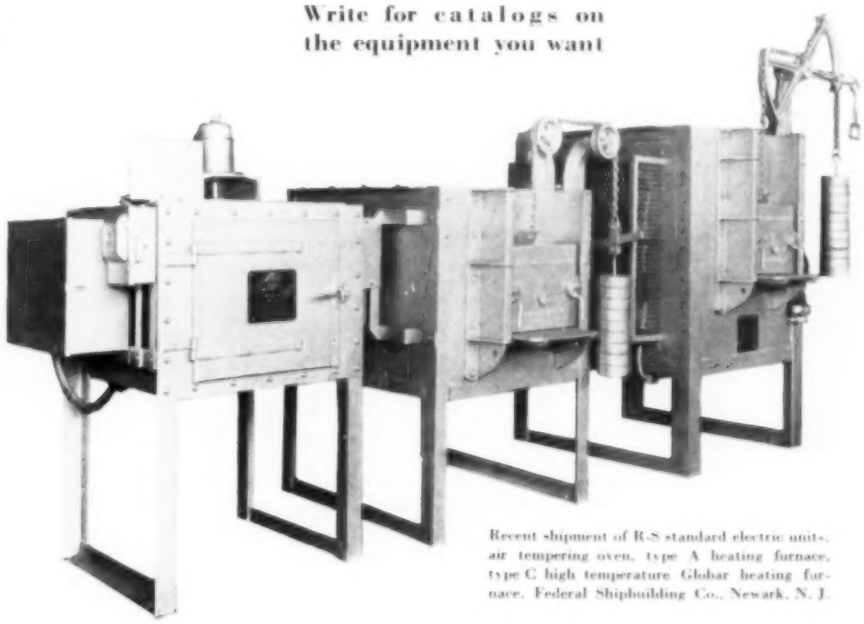

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PICKLING

Hydrogen Formation in Pickling (Die Wasserstoffentwicklung beim Beizen), H. Bablik. *Korrosion und Metallschutz (Berlin)*, vol. 6, no. 10, Oct. 1930, 223-228, 9 figs.

Results of tests show that in material sensitive to pickling hydrochloric acid should be used in pickling process.

Pickling; a Modern Cleaning Method, J. C. Weaver. *Metal Progress*, vol. 18, no. 6, Dec. 1930, 45-49, 5 figs.

Development, advantages and application of principal pickling methods; brief explanation of chemical reaction of acids.

The Pickling of Steel, M. W. Freeman. *Indus. Finishing*, vol. 7, no. 1, Nov. 1930, 60 and 62.

Importance of cleaning sheet steel effectively; what really occurs in general practice; what some of actual losses are and what changes may take place.

SPRING STEEL

Fatigue Strength of Carbon and Alloy Steel Plates as Used for Laminated Springs, R. G. C. Batson and J. Bradley. *Engineering*, vol. 131, no. 3401, Mar. 20, 1931, pages 405-406, 4 figs.

Tests described were started in 1926 and undertaken in order to discover whether substantial improvement could be made in spring plates by grinding or polishing them so as to remove outer skin; later, when such improvement was found, tests were extended to obtain information on effect of heat treatment on fatigue strength, when such treatment was carried out either before or after machining surface of plates. Before Mech. Engrs.

An Investigation of Steels for Aircraft Engine Valve Springs, A. Swan, H. Sutton and W. D. Douglas. *Engineering*, vol. 131, no. 3398, Feb. 27, 1931, pages 314-316, 9 figs.

Apparatus was designed by Savage, of Royal Aircraft Establishment, in which one or more springs operated by cam could be studied stroboscopically, and exact coil movements and positions during rise and fall of cam recorded to magnified scale; it is not intended to deal in detail with results obtained from these experiments, but only to consider broad conclusions as affecting spring failures. Before Instn. Mech. Engrs.

STAINLESS STEELS

Stainless Steel and Its Properties, E. Smith. *Heat Treating and Forging*, vol. 16, no. 11, Nov. 1930.

Physical properties and chemical characteristics of principal types of stainless steel; details of heat treatment and forging. Paper delivered before Am. Drop Forging Inst.

STAINLESS STEELS. Welding of Corrosion Resisting Steels, W. Spraragen. *Welding*, vol. 1, no. 13, Nov. 1930, 897-900, 5 figs.

Chrome irons with carbon less than .20 per cent, chrome steels with carbon more than .20 per cent, chrome-nickel irons with carbon less than .20 per cent, and chrome-nickel steels with carbon more than .20 per cent, are discussed with regard to physical properties; welding technique and procedure are illustrated by microphotograph and examples taken from manufacturer of tanks; heat treating characteristics.

STEEL MELTING

Beitraege zur Klaerung der Schlackenfrage im basischen Siemens-Martin-Ofen (Contribution to Solution of Slag Problem in Basic Open-Hearth Furnace), R. Back. *Stahl und Eisen*, vol. 51, nos. 11 and 12, Mar. 12, 1931, pages 317-324 and Mar. 19, pages 351-357, and (discussion) 357-360, 17 figs.

Behavior of iron and manganese in slag; results of investigations during smelting; behavior of iron in relation to basicity degree of slag; influence of slags in their varying degree of basicity on changes, particularly of manganese and iron.

Hoegfrekvensugnen Ur Elektrisk Anlaeggningssynpunkt (High Frequency Furnaces from Standpoint of Electric Engineers), J. Oesterberg. *Teknisk Tidskrift*, vol. 61, no. 1, Jan. 3, 1931, (Elektroteknik), pages 8-12, 11 figs.

General considerations in design of furnaces for melting of metal, and data on installations in Sweden built by AEG.

Overcoming Certain Operating Troubles in Making Open-Hearth Steel, T. N. Armstrong. *Iron Age*, vol. 127, no. 11, Mar. 12, 1931, pages 864-867.

Consideration of relationship between characteristics of lime used in open-hearth charge and ratio between pig iron and steel scrap; where burnt lime is employed much larger proportion of scrap can be used; troubles connected with use of southern grades of pig iron.

Melting Steel in an Acid Lined Rotating Furnace. *Fuels and Furnaces*, vol. 9, no. 3, Mar. 1931, pages 337-340 and 372, 2 figs.

Results obtained when melting steel in acid-lined rotating furnace.

Fluorspar in the Open Hearth Slag, H. L. Geiger. *Blast Furnace, and Steel Plant*, vol. 19, no. 3, Mar. 1931, pages 412-414.

Survey of work of prominent metallurgists relating to action of fluorspar.

112-Ton Ingot Mould. *Engineering*, vol. 131, no. 3399, Mar. 6, 1931, page 339, 1 fig. on page 338.

Mold made at Sheffield works of Brightside Foundry and Engineering Co., weighs 112 tons; five traction engines required to haul mold along road, and crane of 150 tons capacity was used to load it; ingots, larger than previously made in this country, can be produced in this mold and will be used for production of heavy rotors, hollow forgings for high-pressure chemical vessels, and similar work.

The Design and Operation of Open-Hearth Furnaces—II and III, C. W. Veach. *Rolling Mill Jl.*, vol. 5, nos. 2 and 3, Feb. 1931, pages 91-94 and 106, and Mar., pages 175-178 and 190.

Feb.: Component parts of open-hearth furnaces, functions of each, and general design and construction features. Mar.: Types of refractory materials such as silica brick and chrome brick employed in open-hearth construction; typical construction methods employed in laying checkerbrick.

Tonnage Melting by Coreless Induction, E. F. Northrup. *Fuels and Furnaces*, vol. 9, no. 4, Apr. 1931, pages 473-478, 7 figs.

First of series covering fundamental principles of operation and construction of coreless induction furnace as applied to tonnage melting; development of high-frequency coreless-induction furnace; power requirements and sizes of furnaces and features of construction. This article will be followed by others.

STEEL ROLLING

Formaenderungswiderstand und Werkstoffluss beim Walzen (Deformation Resistance and Flow of Material with Rolling), A. Falk. *Stahl und Eisen*, vol. 51, no. 13, Mar. 26, 1931, pages 388-390.

Letter to editor discussing work of E. Siebel, previously indexed in Dec. 18, 1930, issue of same journal; writer presents new formula for deformation in rolling of any given sections; he is of opinion that increase of deformation resistance with rolling is not due to strengthening of material as result of deformation, but to increase in resistance to flow of material. Reply by Siebel and further polemic is included.

Die Verfestigung einiger Werkstoffe beim Kaltwalzen (Strengthening of Some Metals with Cold Rolling), E. Greulich. *Zeit. fuer Metallkunde*, vol. 23, no. 3, Mar. 1931, pages 91-94, 3 figs.

Exponential law first derived for steels and monel metal is now confirmed for armco iron, copper, and brass 70/30 up to rolling degrees of 30 per cent; strengthening factors for all these materials were calculated and used for analysis of composition and structure; pure metals show less strengthening than alloys.

STEEL TESTING

Redogoerelse foer Noetningsundersoekningar i amslermaskin (Report of Test of Wearing Endurance Properties in Amsler's Machine), C. J. G. Malmberg. *Jerkontorets Annaler*, vol. 85, no. 11, Nov. 1930, pages 572-592, 15 figs.

(Continued on page 138)

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General discussion of wearing research and report on experiments attempting to standardize test methods, so that wearing properties of material may be indexed; wearing properties of steel as depending on carbon contents and heat treatment. Bibliography.

Cupping Tests, T. E. Green. *Mech. World*, vol. 89, no. 2306, Mar. 13, 1931, pages 245-246, 4 figs.

Tests for measuring ductile properties of metal sheets.

Werkstoffpruefung mittels magnetischer Arbeitsverfahren (Materials Testing by Magnetic Methods), E. Gerold. *Stahl und Eisen*, vol. 51, no. 14, Apr. 2, 1931, pages 428-432, 6 figs.

Explanation of magnetic analyses; magnetic measuring methods (1) for detection of defects, such as cracks, piping and segregations, and (2) for judgment of uniform heat treatment and determination of mechanical properties. Bibliography.

Inclusions and Their Effect on Impact Strength of Steel, A. B. Kinzel and W. Crafts. *Am. Inst. Min. and Met. Engrs.—Tech. Pub.*, no. 402, Feb. 1931, 33 pages, 19 figs.

Study to determine quantitative effect of inclusions on physical properties of steel that determine its behavior under dynamic stress; quantitative relation between counted inclusions and impact strength does exist in normalized steels, but factors other than readily visible inclusions are equally important; present commercial rating of inclusions is unreliable with respect to counted inclusions or dynamic tests; tensile-impact test is more reliable as measure of quality.

Beitraege zum Hin- und Herbiegeversuch fuer duenne weiche Stahlbleche (Bending Test for Thin Soft Steel Sheets), J. C. Godsell. *Stahl und Eisen*, vol. 51, no. 10, Mar. 5, 1931, pages 302-303, 1 fig.

Simple and useful device, designed by Jenkins, for carrying out alternating bending test; results of tests with annealing tests at temperatures between 650 and 950 deg. cent.; annealing period of 5 to 90 min. was found to be practical. From Swansea Tech. College Met. Soc. 1930.

A Simple Method of Studying the Stress-Strain Relation in the Notched-Bar Impact Test, T. Kawai. *Tohoku Imperial Univ.—Sci. Reports*, vol. 19, no. 6, Dec. 1930, pages 727-743, 12 figs.

Method for determining energy-strain and stress-strain relation in notched-bar impact test, by using ordinary Charpy machine; from net absorbed-energy-bending relation in impact test, stress-bending relation was obtained by evaluating tangent at each point on curve representing former relation. (In English.)

Wear of Metals, S. J. Rosenberg and H. K. Herschman. *Metals and Alloys*, vol. 2, no. 2, Feb. 1931, pages 52-56, 9 figs.

Types of wear and interpretation of its mechanism; design and operation of principal wear testing machines; difficulties encountered in wear testing and results obtained in laboratory.

Testing Chromium Plate for Resistance to Abrasion, H. C. Wolfe. *Metals and Alloys*, vol. 2, no. 2, Feb. 1931, pages 60-61, 2 figs.

Data on hardness tests of thin chromium plate by means of apparatus utilizing abrasive wheel; graph illustrates effect of current density on hardness of chromium plate.

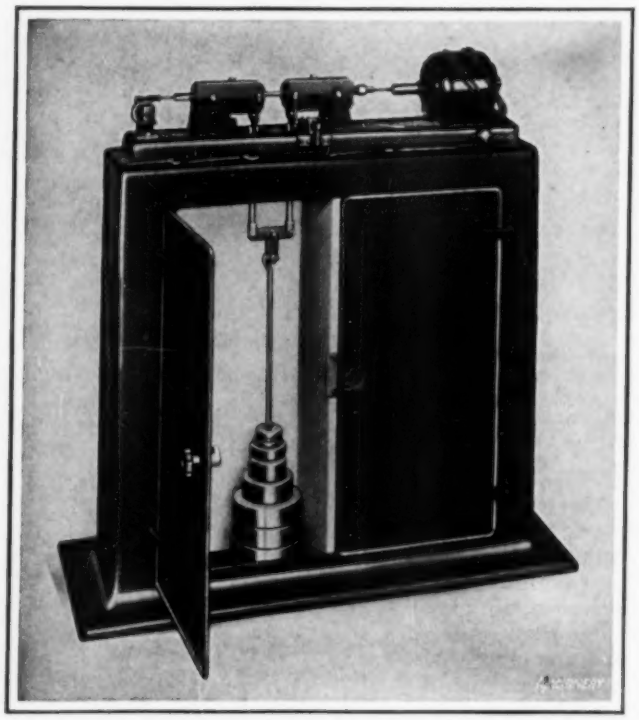
TEMPERATURE EFFECT

Variations de la résilience dans les aciers en fonction de la température (Elasticity of Steel as Function of Temperature), J. Dessent. *Revue Universelle des Mines*, vol. 5, no. 4, Feb. 15, 1931, pages 97-99, 2 figs.

Tests on steels for determination of mechanical properties at various temperatures; results of tests are given in table.

Untersuchung der Ueberhitzungsempfindlichkeit von niedriggekohltem Flusstahl (Study of Fire Resistance of Low-Carbon Ingot Steel), E. Pohl, E. Krieger and F. Sauerwald. *Stahl und Eisen*, vol. 51, no. 11, Mar. 12, 1931, pages 324-326, 2 figs.

Creep of Metals at Elevated Temperatures, P. G. McVetty. *Mech. Eng.*, vol. 53, no. 3, Mar. 1931, pages 197-200, 1 fig.



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ALLOY STEEL

IRON-VANADIUM ALLOYS. Beitrag zur Kenntnis des Systems Eisen-Kohlenstoff-Vanadin (Contribution to Study of Iron-Carbon-Vanadium System), H. Hougardy. *Archiv fuer das Eisenhuettenwesen,* vol. 4, no. 10, Apr. 1931, pages 497-503, 30 figs.

Influence of vanadium on hardness, hardening properties, critical points and grain formation; vanadium imparts to high-carbon steel, properties of lower-carbon steel or of steel free of carbon.

Ueber das ternaere System Eisen-Kohlenstoff-Vanadin (Ternary System Iron-Carbon-Vanadium), R. Vogel and E. Martin. *Archiv fuer das Eisenhuettenwesen,* vol. 4, no. 10, Apr. 1931, pages 487-495, 19 figs.

Results of previous research; solidification of ternary molten charges; transformations of alloys into solid state; separation of carbides; results of tests; analyses of structure.

ZIRCONIUM ALLOYS. Manganese-free Zirconium-treated Steels, F. M. Becket. *Min. and Met.,* vol. 12, no. 293, sec. 1, May 1931, pages 234-236, 10 figs.

Description of comparative test, involving addition of varying amounts of ferro-manganese, ferro-silicon, and zirconium alloys to samples of steel prepared in Heroult electric furnace; results indicate commercial possibility.

CAST IRON

The Deterioration of Cast Iron on Repeated and Prolonged Heating, C. E. Pearson. *Foundry Trade Jl.,* vol. 44, no. 765, Apr. 16, 1931, pages 271-272.

Early scientific experiments made by Carpenter and Rugan in 1909 form basis of present knowledge; new data; microscopic evidence; influence of elements; effect of graphite formation; combined carbon and growth; effects of other elements on low-temperature changes in iron. Before Inst. Brit. Foundrymen.

CORROSION

Verfahren zur Pruefung der Lokalelementtheorie der Korrosion (Method of Testing Local Element Theory of Corrosion), W. Guertler and B. Blumenthal. *Zeit. fuer Metallkunde,* vol. 23, no. 4, Apr. 1931, pages 118-119, 3 figs.

Method is developed for testing local-element theory with elimination of resistance capacity; speed of dissolution of zinc in hydrochloric acid is investigated.

Influence of Stress on Corrosion, D. J. McAdam, Jr. *Am. Inst. Min. and Met. Engrs.—Tech. Pub.,* no. 417, 1931, 39 pages, 14 figs.

General survey of conditions necessary to cause complete failure under corrosion and cyclic stress of relatively high frequency; preliminary study of influence of cyclic stress on corrosion; investigation of corrosion stresses higher than corrosion-fatigue limit; special attention is given to nickel, aluminum bronze, was in corrosion stage and in fatigue stage.

Ueber einen neuen Weg zur Korrosionskurzpruefung (New Method of Rapid Corrosion Testing), L. W. Haase. *Chemische Fabrik,* nos. 15 and 16, Apr. 15, 1931, pages 169-170, and Apr. 22, pages 184-185, 4 figs.

Apparatus and testing method, according to which corrosive agents are continually renewed and control of oxygen content of corrosive liquid is effected; advantages of process.

Korrosion durch Potentialunterschiede und ihre Verhuetung (Corrosion by Potential Differences and Its Prevention), K. O. Schmidt. *Zeit. fuer Flugtechnik und Motorluftschiffahrt,* vol. 22, no. 6, Mar. 28, 1931, pages 177-178, 5 figs.

Investigation of causes of corrosion on light metals and brass, show protective action obtained by use of artificial resins used for separating different metals.

FATIGUE

Ueber die Dauerbiegefestigkeit einiger Eisenwerkstoffe und ihre Beeinflussung durch Temperatur und Kerbwirkung, E. Kaufmann. Berlin J. Springer, 1931, 89 pages, illus., diagrs., charts, tables. 9-r.m.

Report of tests on carbon and chromium-nickel steels and cast iron, to determine their fatigue-resisting properties and variations of these properties with changes in temperature. Bibliography. Eng. Soc. Lib., N. Y.

Utmattningsprov paa jaern och staal (Fatigue Tests on Iron and Steel), A Lundgren. *Jernkontorets Annaler,* no. 1, 1931, pages 1-70, 28 figs.

Survey of most important results obtained in various countries by studies of fatigue of metals; report on investigations at Government Testing Institute, Stockholm, which were conducted with rotating specimens on Alpha testing machine; data on relation between mechanical properties, particularly endurance, heat treatment, yield point, etc., for various steels including nickel-chromium alloys.

FURNACES, INDUSTRIAL

Die Rostfeuerungen industrieller Oefen (Grate Firing of Industrial Furnaces), A. Roitzheim. *Feuerungstechnik,* vol. 19, nos. 3 and 4, Mar. 15, 1931, pages 43-46, and Apr. 15, pages 61-64, 9 figs.

Differences between boiler grate firing as heat generator and furnace grate firing as high temperature producer; temperature sensitivity of flue gases; heat transmission by means of flame; phenomena occurring with half-gas or semi-producer-type furnace; soot in flame; explanation of term half-gas or semi-producer-type-furnace; origin of shaft producer; radiant flames.

Les possibilités du four électrique (Possibilities of the Electric Furnace), P. Marthourey. *Revue de Metallurgie,* vol. 28, nos. 2 and 3, Feb. 1931, pages 101-116, and Mar., pages 139-150, 51 figs.

Development of electric arc furnace in United States, Europe, Japan and China; its possibilities dependent upon design; manufacture of steels with high silicon content; high-test cast iron and malleable cast iron; special applications of electric furnace; control of electrometallurgical products; recommendations for operation of electric furnace.

A Working Furnace Exhibit, H. R. Stevenson. *Elec. Light and Power,* vol. 9, no. 5, May 1931, pages 30-32, 4 figs.

Exhibitive installation of electrical heat-treating equipment, made by Detroit Edison Co., has easily been justified by interest evidenced among industries; it was felt that working exhibit of type of furnace which possessed greatest sales possibility, would easily prove to be worth amount of time and effort expended in securing it; some of exhibits are illustrated and described.

Remarques sur l'emploi du four à induction à haute fréquence pour la fabrication des aciers (Use of High-Frequency Induction Furnace for Manufacture of Steel), M. Lacroix. *Revue de Metallurgie,* vol. 28, no. 3, Mar. 1931, pages 151-161, 5 figs.

Experiences with 250-kg., 120-kva. furnace of Ajax-Northrup type installed in St. Francois steel works of St. Etienne, charged by 150-kva. converter set supplied by Société Alsthom of Belfort; operating data; current consumption and yield; control of steel manufacture; advantages of high-frequency furnace for manufacture of high-grade steels. Bibliography.

The Berliner-Joyce Aircraft Corporation Plant, W. S. Scott. *Heat Treating and Forging,* vol. 17, no. 4, Apr. 1931, pages 394-398, 5 figs.

Design and operation of electric furnaces and ovens; tables give heat treatment specifications for aluminum alloys and alloy steel.

Ueber Regelung der Temperatur in industriellen Oefen—IV (Temperature Control in Industrial Furnaces), V. Paschkis. *Forschung auf dem Gebiete des Ingenieurwesens,* vol. 2, no. 2, Feb. 1931, pages 57-64, 9 figs.

Experimental investigation and mathematical formulation of relations between temperature rise and heat output reserve of furnace; hyperbolic characteristics of non-sensitivity.

Tonnage Melting by Coreless Induction—I, E. F. Northrup. *West. Machy. World,* vol. 22, no. 4, Apr. 1931, pages 183-186, 5 figs.

Authentic information on metallurgical results obtained from high-frequency induction furnaces and selected bibliography of more important articles which have appeared about these furnaces since their introduction in 1918.

High-Frequency Induction Furnace Affords Heat Uniformity, H. C. Bigge. *Steel,* vol. 88, no. 19, May 7, 1931, pages 39-41 and 57, 3 figs.

Operation and construction of electric coreless induction furnace of 1200 lb. capacity at plant of Bethlehem Steel Co., Bethlehem; data on composition of high speed steel and tool steels melted.

(Continued on page 142)

What is "MAXIPRESSING"?

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IT is generally recognized that definite economies exist in the field of coining, shaping or forming of parts to final size by pressure.

Attempts to obtain these economies in the past have only been partially successful. The heavy pressures required for this class of work have heretofore confined the operation to slow toggle type presses, which were not productive.

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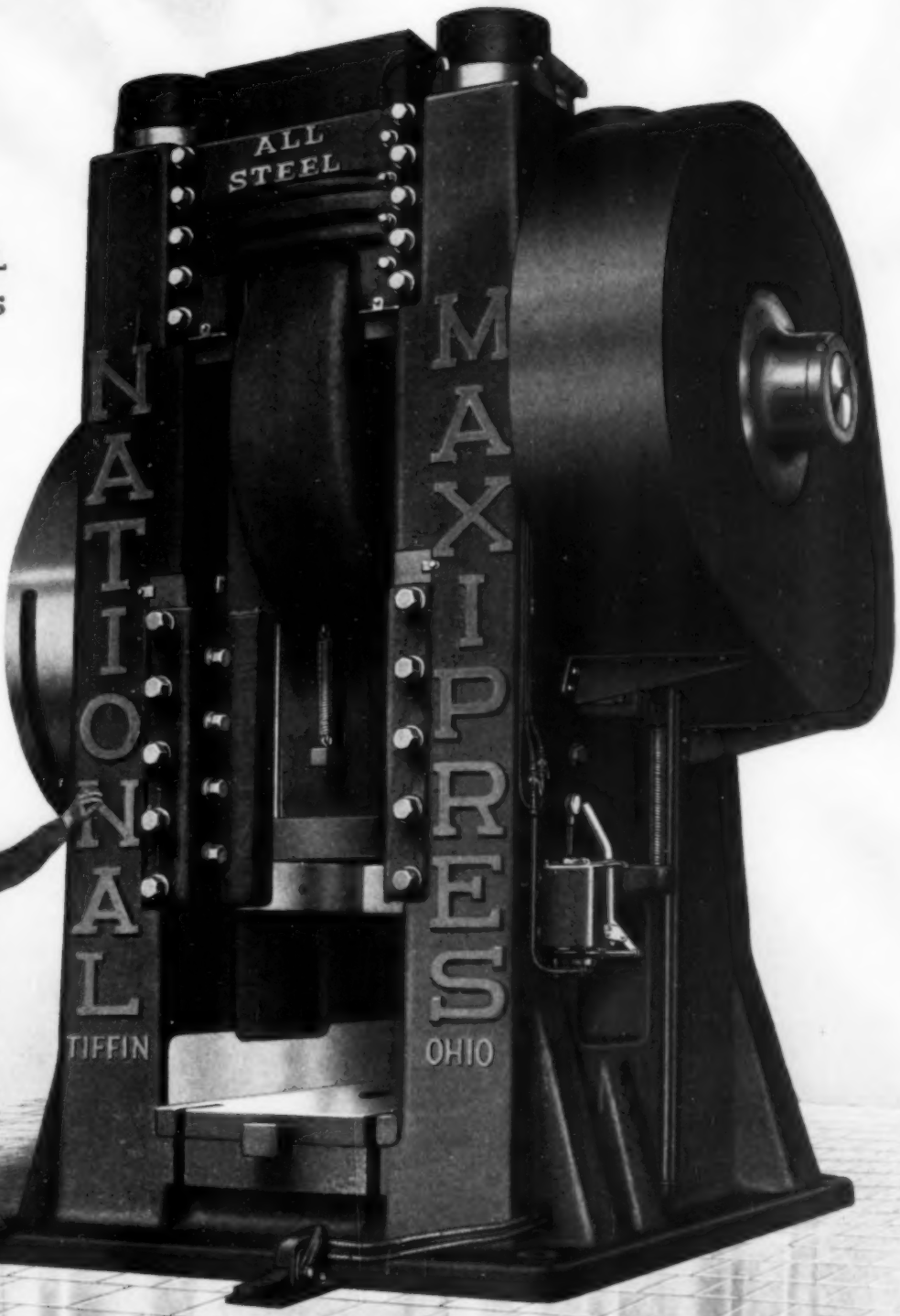

MAXIPRES

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2000 Kw., 75 Ton Furnace Anneals Large Castings, A. G. Hotchkiss. *Elec. World*, vol. 97, no. 17, Apr. 25, 1931, page 768, 2 figs.

To handle heat treatment of large single-unit steam turbine and electric generator castings properly, General Electric Co. has installed at Schenectady plant 2000 kw. car-bottom type electric annealing furnace with maximum loading capacity of 75 tons; furnace not only handles largest structures now heat treated, but is of sufficient size to accommodate larger machines of future.

HEAT TREATMENT

Ermittlung der Temperatur- und Waermeleitzahl von Gluehgut aus dem gemessenen Temperaturverlauf (Determination of Temperature and Heat-Conductivity Coefficient of Material to be Annealed from Measured Temperature Curve), A Schack and E. Auhagen. *Archiv fuer das Eisenhuettenwesen*, vol. 4, no. 10, Apr. 1931, pages 469-474, 9 figs.

Principles for calculation of temperature of materials to be annealed; determination of heat and temperature coefficients of steel ingots and of stratified annealing charge of steel wire, steel and cast-iron shavings; possibility of precalculating temperature trend in case of annealing charge.

Circulation Important in Quenching, H. J. French. *Black and White (Metal Edition)*, vol. 3, no. 6, May 1931, pages 4-7, 3 figs.

Factors which influence consistently uniform results in quenching bath; spray quenching; control of flow in liquid bath.

HIGH SPEED STEEL

Selecting and Hardening High-Speed Steel, A. Heller. *Am. Mach.*, vol. 74, no. 17, Apr. 23, 1931, pages 635-638, 3 figs.

Heat treatment and hardening characteristics of cobalt and tungsten steels; graphs illustrate characteristics of three tungsten high-speed steels and two cobalt high speed steels, showing that latter harden at lower temperature; effect on hardness by soaking at various temperatures for varying lengths of time.

Selecting and Hardening High-Speed Steel—II, A. Heller. *Am. Mach.*, vol. 74, no. 18, Apr. 30, 1931, pages 685-688, 8 figs.

Methods of testing strength and toughness of tungsten and cobalt steels when lower hardening temperatures are used with short soaking periods.

Selecting and Hardening High-Speed Steel—III, A Heller. *Am. Mach.*, vol. 74, no. 19, May 7, 1931, pages 726-728, 3 figs.

Technique of tempering tungsten and cobalt high-speed steels with particular regard to volume and hardness changes; consideration of physical properties of steel for use in various tools.

IRON

Perfecting Magnetic Iron. *Engrs. and Eng.*, vol. 48, no. 4, Apr. 1931, pages 92-93.

Review of T. D. Yensen's work; one of his main objects has been to determine properties of really pure iron; commercially Yensen's most important results have come from study of iron-silicon and iron-nickel alloys; Hipernik (alloy of half iron and half nickel) is another product, closely connected with his activities.

Remarques relatives à l'influence des gaz occlus sur les propriétés mécaniques des produits métallurgiques (Notes on Effect of Occluded Gases on Mechanical Properties of Metallurgical Products), L. Guillet and J. Cournot. *Génie Civil*, vol. 98, no. 16, Apr. 18, 1931, pages 402-403.

Abstract of paper, presented at Academie des Sciences, giving critical review of work of Guichard, Clausmann, Billon and Lanthony as to effect of occluded hydrogen on hardness of electrolytic iron; iron and steel gas occlusions.

Om syrehaltiga strukturelement i tackjaern (Structure Elements Containing Oxygen in Iron-Carbon Alloys), C. Benedicks. *Jernkontorets Annaler*, no. 3, 1931, pages 147-159, 18 figs.

By mixing molten pig iron with about 5 per cent of magnetite, structure elements with high content of oxygen were obtained, which could be observed microscopically without etching; structural characteristics of oxy-perlite and solidification structure containing idiomorfic cementite crystals, austenite with dissolved oxygen (oxy-austenite) and ferrous oxide.

METAL ANALYSIS

Uber den Kohlenstoffgehalt in der Eta-Phase (Carbon Content in Eta Phase), H. Hanemann. *Archiv fuer das Eisenhuettenwesen*, vol. 4, no. 10, 1931, pages 485-486, 10 figs. on supp. plate.

Review of previous work; investigations of quenched troostite; discussion of diffusion phenomena during annealing of hardened steel; tests on carbon distribution between eta gamma phases.

Ueber die Vorgaenge bei der Ausbildung des Martensitgefueges (Phenomena Occurring with Formation of Martensite Structure), H. Haneman, K. Herrmann, U. Hofmann and A. Schrader. *Archiv fuer das Eisenhuettenwesen*, vol. 4, no. 10, Apr. 1931, pages 479-484, 16 figs. partly on supp. plates.

Structural constituents of martensite system; preparation of samples; X-ray analyses; results; eta phase and its changes with annealing; pseudomorphism in hardened steel; theta phase; evaluation of transformation phenomena.

Die Aetzung mit alkalischer Natriumpikratloesung und ihre Anwendung zur Erforschung der Anlassvorgaenge im gehaerteten Stahl (Etching with Alkaline Sodium-Picrate Solution and Its Application to Investigation of Annealing Phenomena in Hardened Steel), H. Hanemann and A. Schrader. *Archiv fuer das Eisenhuettenwesen*, vol. 4, no. 10, 1931, pages 475-477, 23 figs. on supp. plates.

Le Chatelier etching process; etching of cementite, ferrite, austenite, quenched troostite, zeta and theta constituents.

Microscopic Investigation of Metals, V. N. Krivobok. *Engrs. Soc. West Penn.—Proc.*, vol. 47, no. 2, Feb. 1931, pages 45-62, 17 figs.

Four main purposes of metallurgy; methods of steel treating for microscopic analysis.

METALS ANALYSIS

Radiation from Metals Bombarded by Low-Speed Electrons, F. L. Mohler and C. Boeckner. *U. S. Bur. Standards—Jl. Research*, vol. 6, no. 4, Apr. 1931, pages 673-681, 4 figs.

Small probe surface at positive potential in discharge may draw current of many amperes per square centimeter with potential gradient limited to thin sheath over surface; under such conditions continuous spectrum is emitted by metal surfaces in caesium, potassium, and helium discharges; comparison with published data on photoelectric effect of radiation from electron bombardment of metals indicates that magnitude of effects below 10 volts can be explained by this continuous spectrum.

Nouvelle méthode pour la détermination de la teneur en soufre en cinq minutes (New Methods for Determining Sulphur Content in Five Minutes), A. Guedras. *Aciers Spéciaux Metaux et Alliages*, vol. 6, no. 66, Feb. 1931, pages 75-80, 4 figs.

Method of determining sulphur content by combustion in oxygen current with accuracy of 0.001 per cent, according to Holthaus, and advantages as compared to methods of Francke.

NON-FERROUS

Mitteilungen der Deutschen Gesellschaft fuer Metallkunde, (Report of German Metallographic Society). *Zeit. fuer Metallkunde*, vol. 23, no. 4, Apr. 1931, pages 129-132.

Work of professional committees; report of foundry committee at meeting Jan. 23, 1931; brief reviews of papers and discussions.

Gegossene Aluminiumbronzen—IV (Cast Aluminum Bronze), W. Claus and F. Goederitz. *Giesserei*, vol. 18, no. 16, Apr. 17, 1931, pages 319-326, 14 figs.

Theory of shrinkage; systematic comparison of shrinkage phenomena of aluminum bronze and tin bronze; linear and cubic or volume shrinkage; relation of nature of shrinkage to distribution of total volume shrinkage over liquid and solid state; features accompanying shrinkage, such as micropiping. See Engineering Index 1930, p. 105, for reference to previous articles of this series.

The Properties of Pure Nickel, L. Jordan and W. H. Swanger. *Bur. Standards—Jl. Research*, vol. 5, no. 6, Dec. 1930, pages 1291-1307, 5 figs.; see also *Metal Industry (Lond.)*, vol. 38, no. 16, Apr. 17, 1931, pages 407-408.

Physical properties of two fairly pure samples of electrolytic nickel supplied by International Nickel Co.

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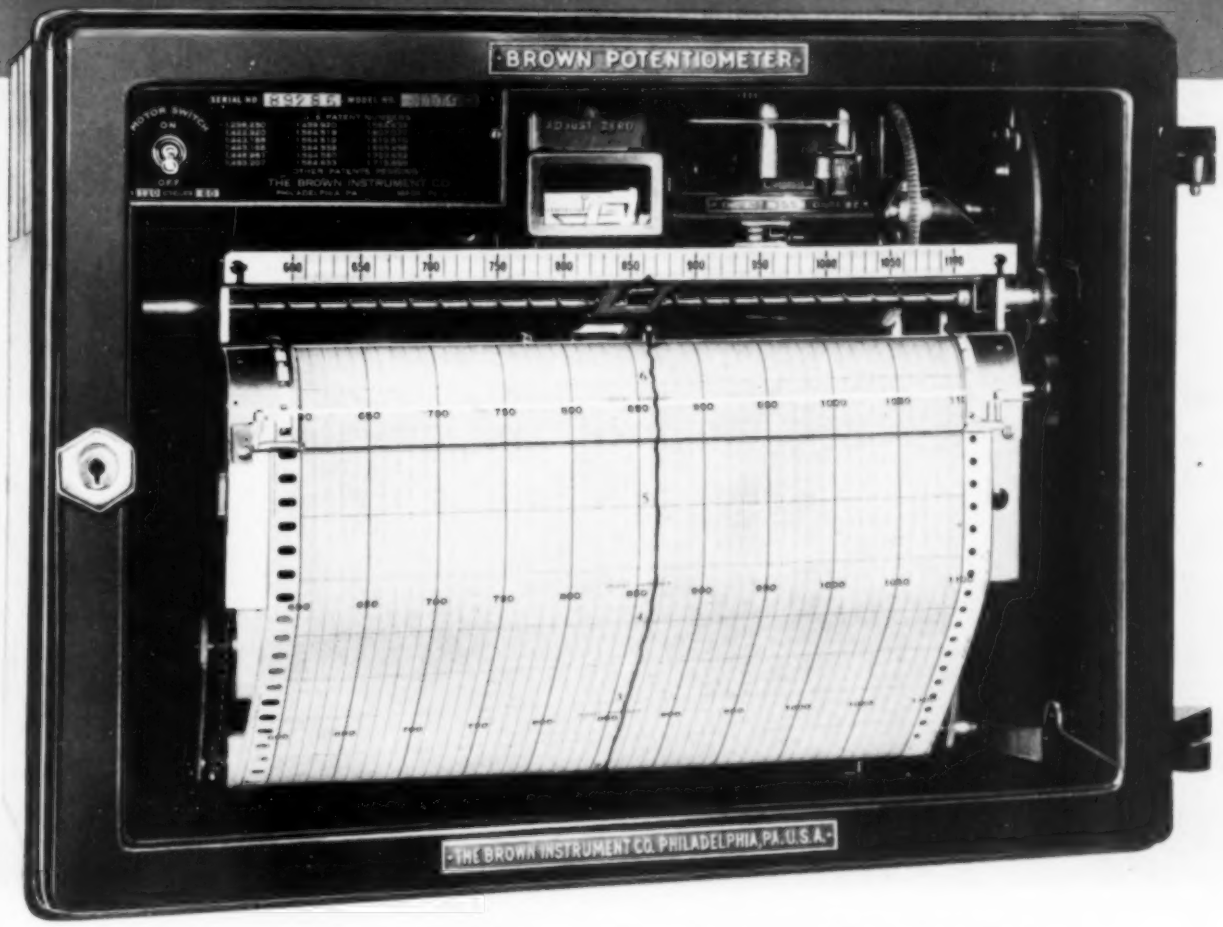

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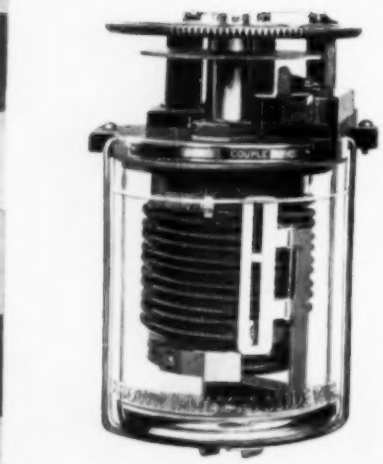

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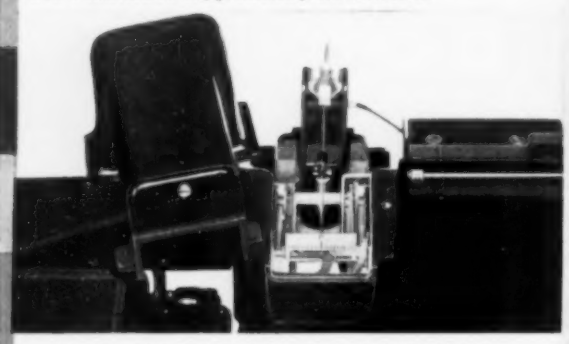

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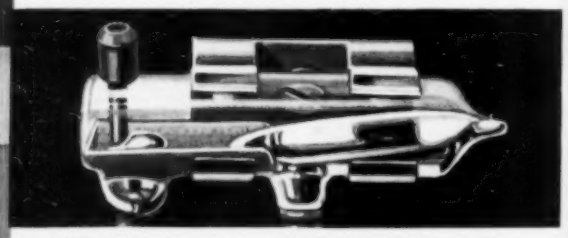
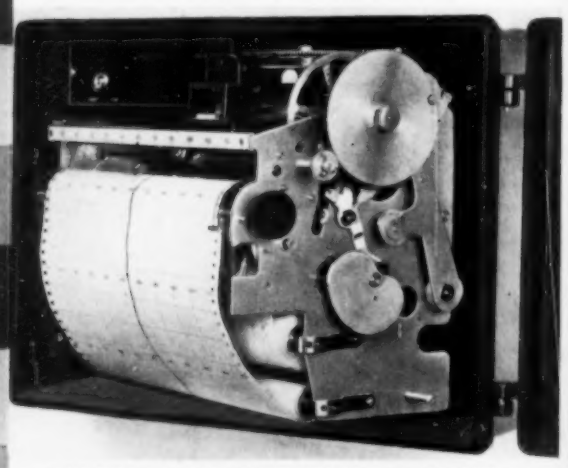
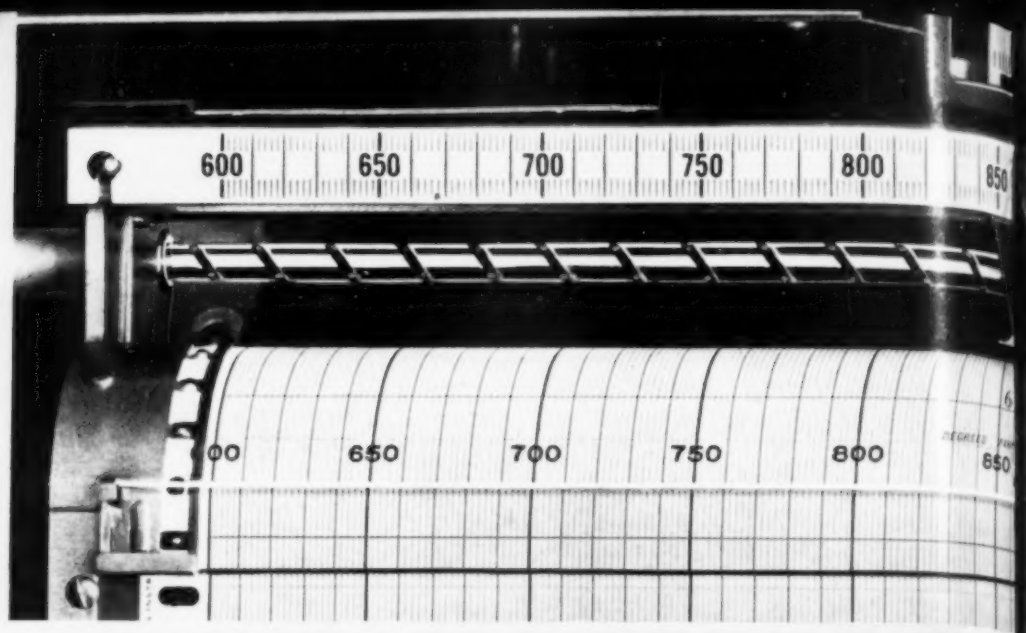


MERCURY IN GLASS SWITCHES FOR AUTOMATIC CONTROL—Controller operates mercury switches, eliminating relays. No open arcs.



POSITIVE NON-SLIP DRIVING CLUTCH—Rugged, positive and simple. Entire mechanism on swinging frame. Note also chart reroll.



FOR APPLICATIONS REQUIRING MAXIMUM ACCURACY

POTENTIOMETER Pyrometers, because of certain characteristics, are favored by many for the accurate measurement of temperature.

Potentiometer Pyrometers were first developed for laboratory service—to be used by technicians, skilled in the handling of delicate instruments. They were not so well adapted to the rough-and-ready conditions of service in the shops where industrial processes are actually carried on.

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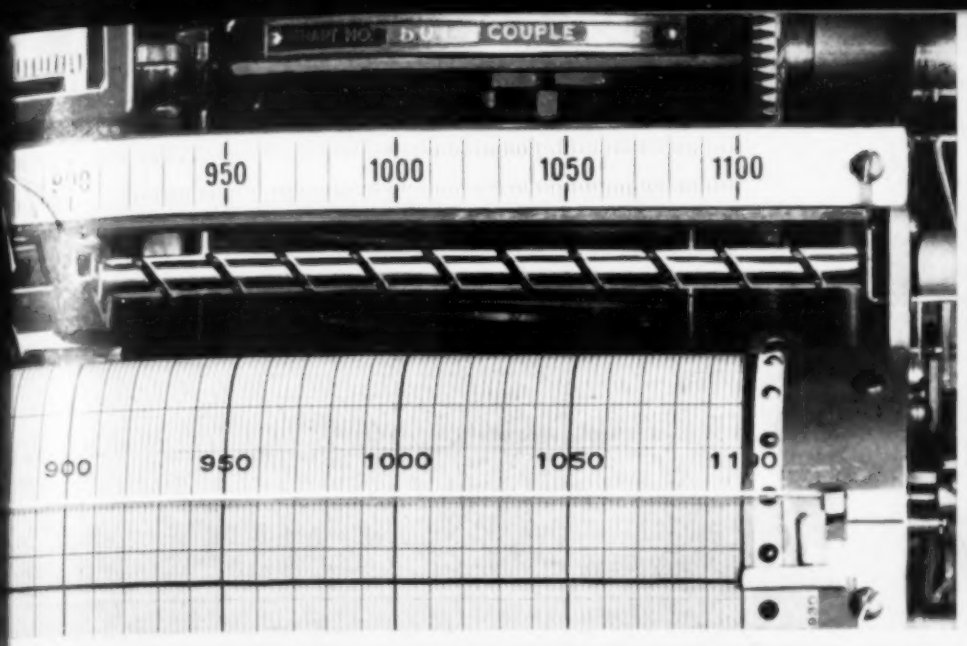

FEATURES THAT MAINTAIN UNFAILING ACCURACY

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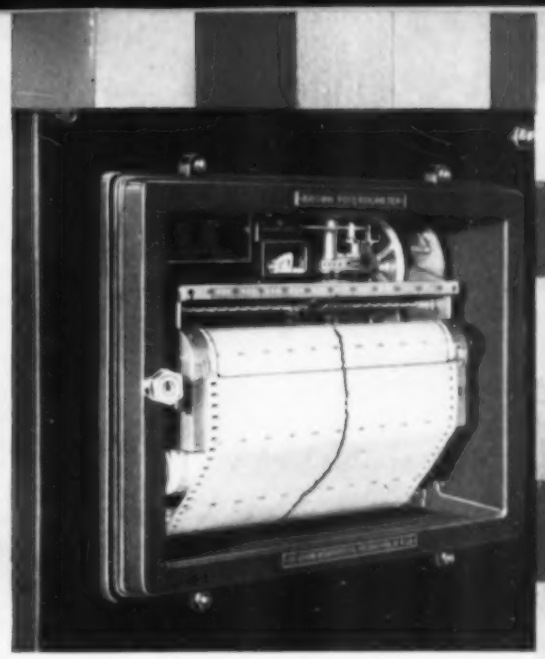
The Brown Potentiometer Pyrometer Chart is 12″ wide, divided into 300 divisions for some ranges. Such a chart can easily be read to 1/2 a scale division. This means that the temperature record can be observed to 1/6 of 1%.

In any wide chart recorder, expansion and contraction of the chart paper tends to produce an error which may amount to as much as 1% (15° at 1500°). With the Brown Recording Potentiometer Pyrometer a humidity compensator accurately compensates for this possible error. This is an exclusive Brown feature.



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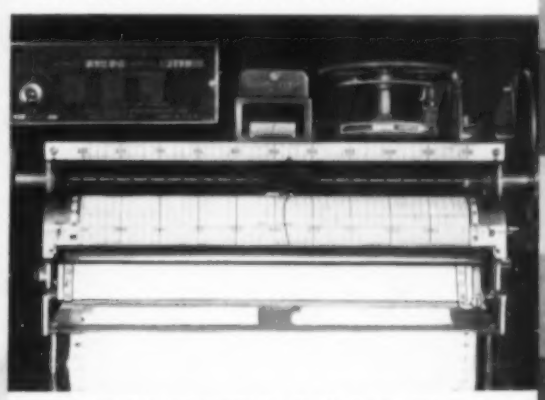
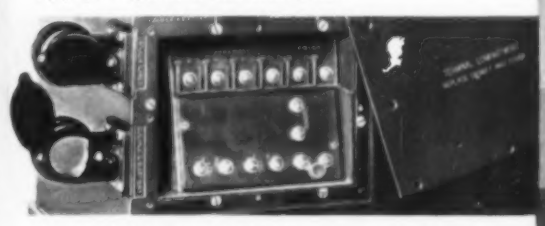


HUMIDITY COMPENSATOR FOR CHART—Automatically compensates for possible errors caused by paper expansion and contraction.



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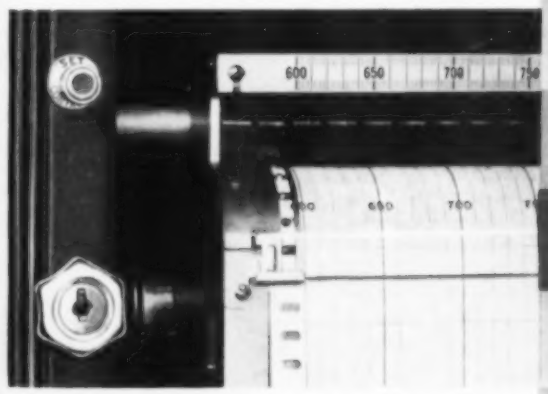

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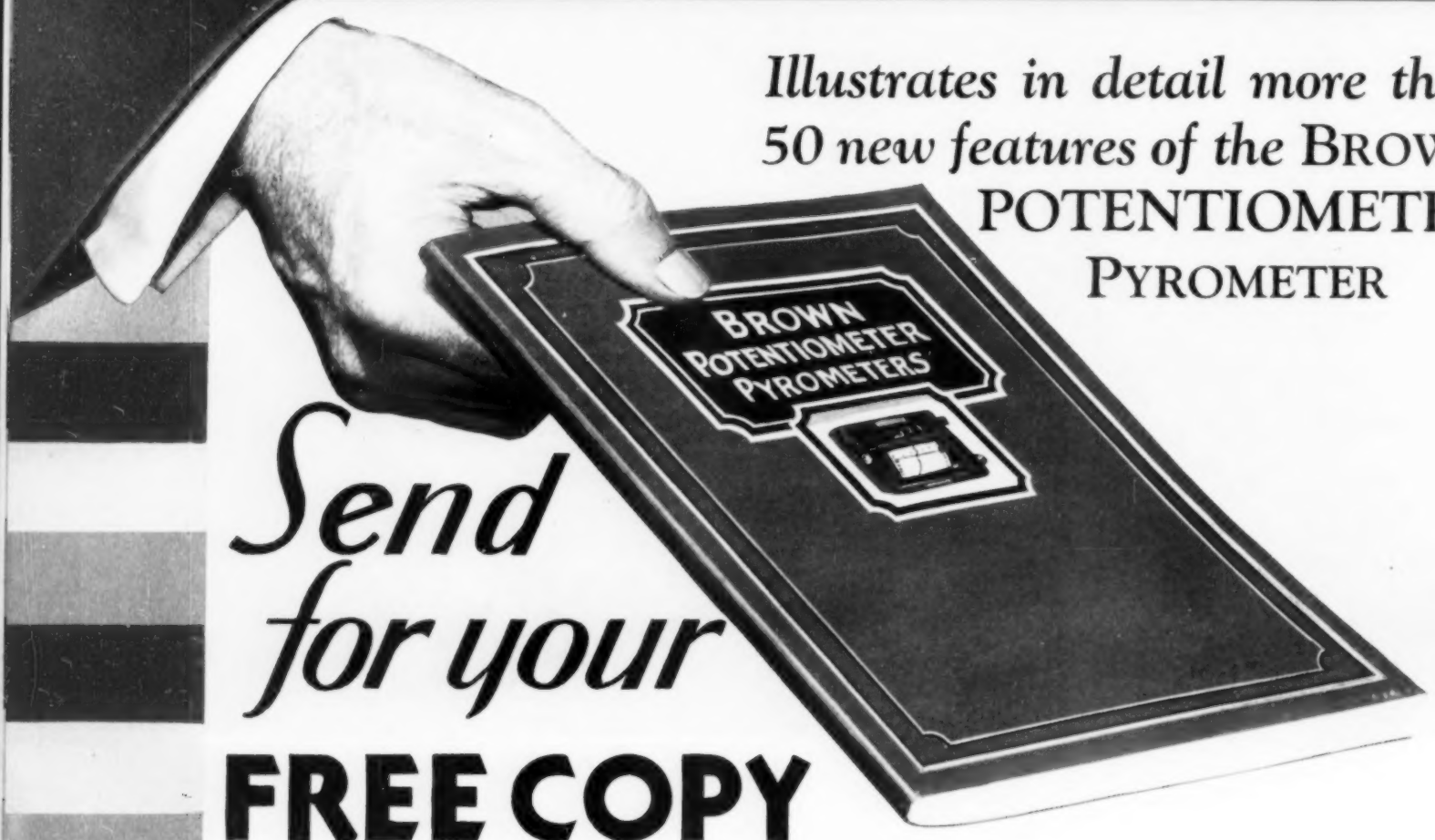

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TUBES

Herstellung nahtloser Rohre (Manufacture of Seamless Tubes). *Internationale Zeit. fuer Bohrtechnik, Erdoelbergbau und Geologie,* vol. 39, nos. 5 and 6, Mar. 1, 1931, pages 35-40 and Mar. 15, pages 41-44, 25 figs.

Review of developments in manufacturing processes; Pilger process; Swedish process; automatic method employing so-called automatic two-high mill; continuous process; hot drawing and reducing rolls; factors influencing choice of process. From Demab Nachrichte, May 1930.

The Push Bench Process for the Manufacture of Seamless Steel Tubes, H. G. Reid. *S. African Instn. Engrs.—Jl.,* vol. 29, no. 6, Jan. 1931, pages 119-126 and (discussion) 126-127, 13 figs.

Drawing methods and equipment of plant at Vereeniging, South Africa; calculation of forces and stresses in process which consist principally in hot drawing of hollow pierced bloom over mandrel.

WELDING

Stresses in Large Fillet Welds, C. H. Jennings. *Product Eng.,* vol. 2, no. 3, Mar. 1931, pages 116-118, 5 figs.

Within certain limits, larger weld presents larger residual stresses and lower yield point and ultimate unit strength; residual stresses are greatly affected by welding procedure; typical bending moment-deflection curve plotted from test data to determine yield point; strength data on fillet weld bend tests.

Die Metallographie der Widerstandschweissung des Eisens (Metallography of Resistance Welding of Iron I), F. Goldmann. *Elektroschweissung,* vol. 2, no. 3, Mar. 1931, pages 41-47, 16 figs.

Structure at weld as dependent on extent and duration of heating, cooling time for seam, spot and butt welding of carbon steel; iron alloys and other kinds of iron and of iron with metallic coatings.

Compressive Tests of Jointed H-Section Steel Columns, J. H. Edwards, H. L. Whittemore and A. H. Stang. *U. S. Bur. Standards—Jl. Research,* vol. 6, no. 2, Feb. 1931, pages 305-337, 36 figs.

Investigation undertaken to determine experimentally distribution of stress near ends of columns and in bearing plates; specimens consisted of two 3-ft. lengths of H-section steel columns of unequal depth placed end to end with flat steel plate between them; compressive loads were applied in direction of axes of columns.

Elektrisch Geschweisste Konstruktionen (Electrically Welded Structures), H. Hintz. *Stahl und Eisen,* vol. 51, no. 9, Feb. 25, 1931, page 258, and (discussion) 258-260.

Comparison of welded and riveted joints; results of tests of both types of joints; advantages of electric welding, especially machinery manufacture.

Proposed Specifications for Fusion Welding. *Mech. Eng.,* vol. 53, no. 3, Mar. 1931, pages 230-232.

Proposed revisions and additions to code for unfired pressure vessels for fusion-welded construction.

Fillet Welds Determined Graphically, J. R. Griffith. *Welding,* vol. 2, no. 3, Mar. 1931, pages 163-165, 2 figs.

Method of finding size and length of fillet welds for member in pure tension or compression by means of nomographic charts.

Fatigue Properties of Welds, J. B. Johnson. *Welding,* vol. 2, no. 3, Mar. 1931, pages 159-162 and 165, 7 figs.

Investigation of various factors controlling fatigue properties of different types of welds; graphs illustrate fatigue properties of chrome-molybdenum and butt welded joints and of weld metal and typical welded joints in carbon steel tubing; conclusions as to proper technique of the welding operation.

WELD TESTING

Neuzeitliche loet-und Schweissverfahren und die Nachpruefung der erzeugten Naehte (Modern Soldering and Welding Methods and Inspection of Seams), H. Klopstock. *Werkstattstechnik,* no. 5, Mar. 1, 1931, pages 131-135, 8 figs.

Survey of soldering methods and solders for all kinds of metals and their practical applications; economy of modern welding methods obtained by increased welding velocity with particular regard to Arcogen and Arcatom methods; design of instrument for testing quality of seam.

The Strength of Arc-Welded Joints, F. R. Freeman. *Instn. Civil Engrs.—Minutes of Proc.,* no. 4808, vol. 231, pt. 1, 1930-1931, 25 pages, numerous figs. partly on supp. plates.

Dorman, Long and Company tests to destruction on full-size specimen joints welded under workshop conditions; effect of variation in size and length of fillet, thickness and width of plates joined, etc.; physical properties of plates, weld-metal, and electrodes used; tests of composite joints; "quarsi-arc mild steel" electrode used throughout; few tests made with "quasi-arc uranium" electrode; rules for design, working-stresses, etc., of fillet welds and butt welds.

Auffindung und Darstellung von Spannungsrissen an Schweissungen (Determination and Representation of Cracks in Welds), H. Kemper. *Autogene Metallbearbeitung,* vol. 24, no. 4, Feb. 15, 1931, pages 57-60, 5 figs.

Advantages of different methods for discovering hair cracks with particular regard to use oil and chalk, and use of sensitized paper subsequent to treatment of welds with ammonia sulphide.

Certifying Welds, H. L. Whittemore. *Welding Engr.,* vol. 16, no. 3, Mar. 1931, page 49.

Suggestions regarding subjecting of welding procedure to engineering control and assurance of certificates or documents testifying to quality of welds.

X-RAY

A New X-Ray Spectrograph for Wave-Length Determinations in Air, S. Zeidenfeld. *Rev. Sci. Instruments,* vol. 2, no. 3, Mar. 1931.

Instrument is vitally necessary in all channels of research appertaining to x-ray spectrography; its performance in both qualitative and quantitative analyses has been demonstrated and owing to good accuracy permissible, spectrograph should be found indispensable for new wave-length determinations (rare-earths, etc.) in region of O.5-2.OA approximately.

X-Rays in Metallurgical Research—I. *Metallurgist (Supp. to Engineer),* Feb. 27, 1931, pages 26-28, 1 fig.

In article by Westgren, indexed in Engineering Index 1930, from Nov. issue of Zeit. fuer Metallkunde, author takes objection to statement by Rosenhain in paper before Institute of Metals (See Engineering Index 1929, p. 1148), which is interpreted as opinion adverse to usefulness of x-rays for research into constitutional diagrams; it is believed Westgren tends to proceed to other extreme by emphasizing undoubted advantages that x-ray methods present without mentioning difficulties that may render them in some cases unsuited.

The Influence of the Crystal-Orientation of the Cathode on That of an Electrodeposited Layer, W. A. Wood. *Phys. Soc.—Proc.,* vol. 43, pt. 2, no. 237, Mar. 1, 1931, pages 138-141, 6 figs.

Influence of crystal-orientation of cathode on that of electro-deposited layer is studied by X-ray methods for cases of copper and nickel, respectively, deposited on rolled copper.

X-Rays in Metallurgical Research—II. *Metallurgist (Supp. to Engineer),* Mar. 27, 1931, pages 35-36.

Review and discussion of Westgren's investigations; in cases where second phase is present in such small quantities that it cannot be detected by X-ray methods when associated with matrix, it is still possible, in some instances, to obtain useful information; classification of alloy phases according to their crystal structure; Westgren, it seems clear, is justified in his contention that X-ray analysis should be more widely used by metallurgists than it is at present.

On the Regularities of X-ray Spark Spectra, S. Idei. *Tohoku Imperial Univ.—Science Reports,* vol. 19, no. 5, Dec. 1930, pages 551-558, 6 figs.

By regularities found it was possible to correlate certain spark lines found by several investigators. Bibliography. (In English.)

New Applications for the X-ray Are Continually Being Discovered D. S. Brown. *Elec. Jl.,* vol. 28, no. 2, Feb. 1931, pages 88-90, 4 figs.

Annual business in X-ray tubes and equipment amounts at present to about $30,000,000 for world at large and about $15,000,000 for United States; medical uses; therapeutics; industrial uses; applications and art and science; future outlook.

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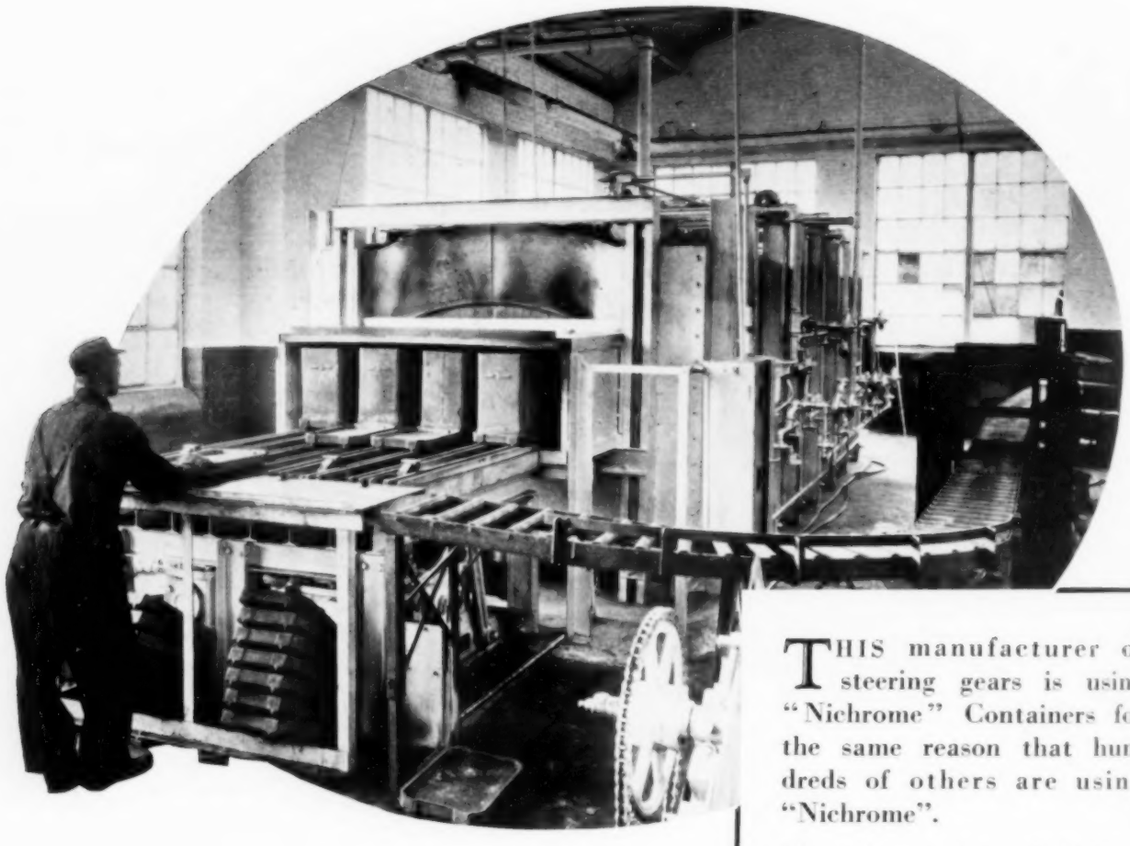

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